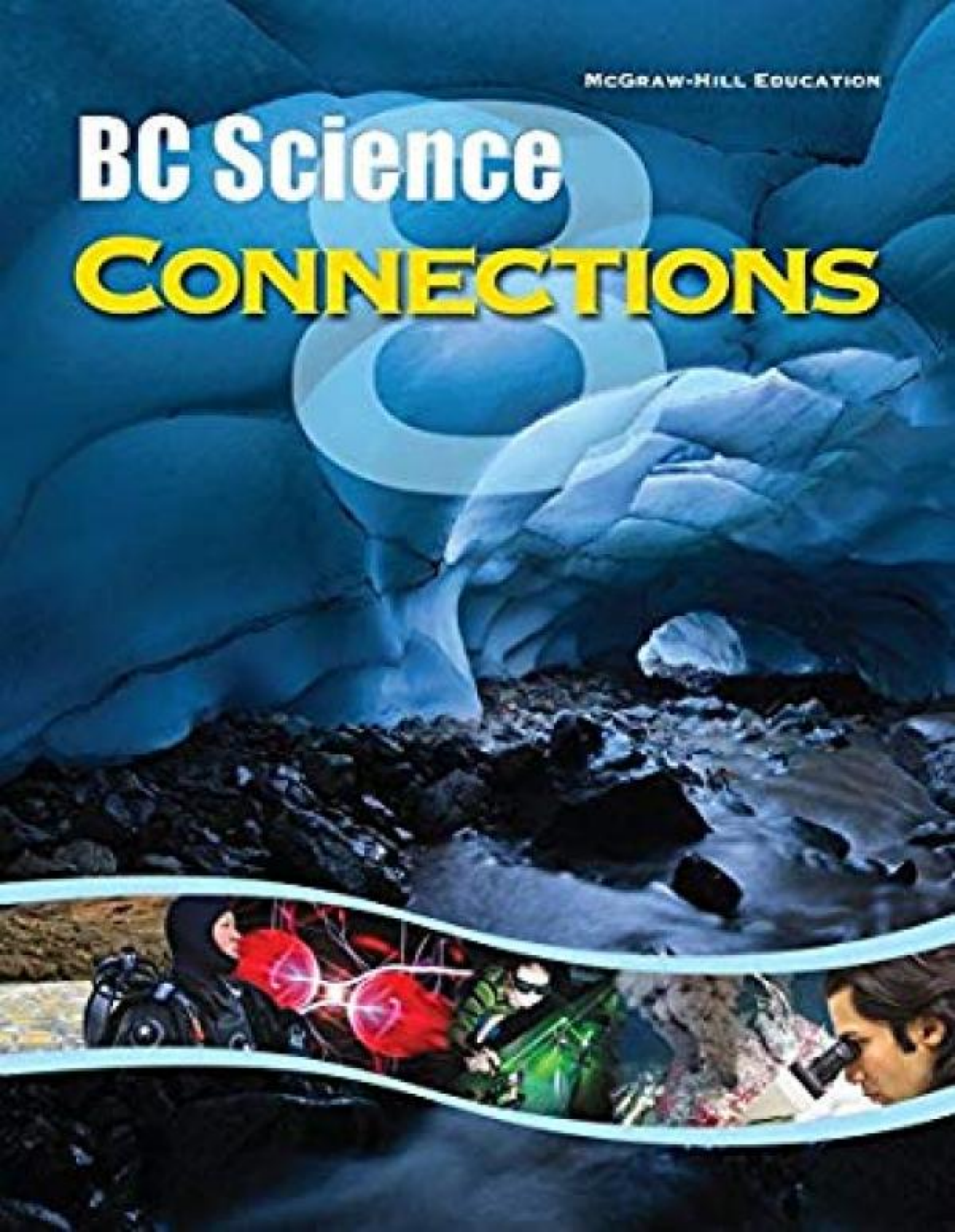
McGRAW-HILL EDUCATION

BC Science 8 CONNECTIONS



UNIT 1

Life processes are performed at the cellular level

In our high-tech world, one of the hottest areas of study is nanotechnology—the science and the technology of the very, very small. In this field, researchers are working to create an artificial cell that can replicate on its own and change to suit the conditions it encounters. To achieve this goal, the researchers must create artificial components that mimic structures found in real cells. By studying living cells, researchers hope to create the perfect fake!

> **"Artificial cells can now be of macro, micro, nano and molecular dimensions.... We have only just touched the surface of the enormous potential of artificial cells.... The result of the pooling of talents [in this] area will lead to progress beyond anyone's imagination."**
>
> *Dr. Thomas Ming Swi Chang, inventor of the first artificial cell and recipient of the Order of Canada*

- How do you think artificial cells could be used?
- What do you think of the idea of artificial cells?
- What questions do you have about—this photo? the introduction? the quotation? the title for this unit? ...?

UNIT 1

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations to explore cellular processes and/or the interactions of micro-organisms with other living things
- Develop and use models and other methods to show connections between cellular processes, the immune system, and/or the spread of disease
- Seek patterns and connections to describe relationships between micro-organisms and other living things
- Develop evidence-based explanations about the role of vaccines and antibiotics in human health
- Use scientific understandings to evaluate the impacts of disease on human populations

ESSENTIAL QUESTION

How are life processes affected by our interactions with microbes and other living things?

TOPIC 1.1:
What are the characteristics of living things?

Some things you will do:

- observe and ask questions about the natural world
- experience and interpret the local environment
- consider different ways of knowing and local knowledge as sources of information

Some things you will come to know:

- processes associated with living things
- how scientists classify something as living or non-living

TOPIC 1.2:
Where do living things come from?

Some things you will do:

- identify questions you have about the natural world
- use a microscope to observe, measure, and record
- become aware of assumptions and bias in your work

Some things you will come to know:

- the three key statements of the cell theory
- why viruses challenge the idea of what makes something living or not

TOPIC 1.3:

How are cells different from one another?

Some things you will do:

- co-operatively design projects
- measure and control variables through fair tests

Some things you will come to know:

- features that scientists use to classify cells
- what bacteria are and why they are prokaryotic cells
- how plant cells and animal cells are similar and different

TOPIC 1.4:

What interactions occur between humans and micro-organisms?

Some things you will do:

- demonstrate an understanding and appreciation of evidence
- consider social, ethical, and environmental implications of findings
- ensure safety and ethical guidelines are followed in investigations

Some things you will come to know:

- the role of microbes in nature
- positive and negative interactions we have with microbes

TOPIC 1.5:

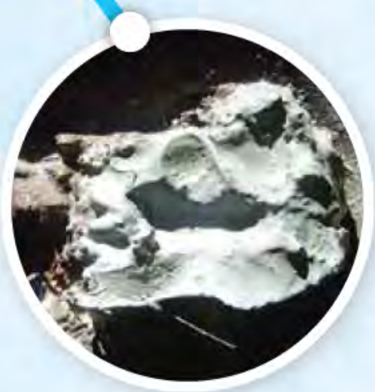
How does the body protect us from pathogens?

Some things you will do:

- measure and control variables through fair tests
- construct and use a range of methods to represent patterns or relationships in data
- contribute to care for self, others, community, and world

Some things you will come to know:

- the immune system's lines of defence that protect us from microbes and infection
- effects and consequences of outbreaks of disease



TOPIC 1.6:

What medicines help protect us from microbes that make us sick?

Some things you will do:

- consider Aboriginal perspectives and knowledge as sources of information
- contribute to care for self, others, community, and world
- seek patterns and connections in data
- use scientific understandings to identify relationships and draw conclusions

Some things you will come to know:

- different cultures contribute medicines, technologies, and understandings to treat disease
- vaccines and antibiotics can help in treating disease

UNIT 1

Summary

ESSENTIAL QUESTION

How are life processes affected by our interactions with microbes and other living things?

TOPIC 1.1:
What are the characteristics of living things?

- Living things are made of cells, take in nutrients, use energy, and produce waste.
- Living things respond to stimuli, grow, and reproduce.

Key Terms

cell

TOPIC 1.2:
Where do living things come from?

- Living things come only from other living things.
- Scientists debate about whether viruses are living things or not.

Key Terms

cell theory

virus

TOPIC 1.3:

How are cells different from one another?

- Scientists classify cells into two types based on the presence or absence of a nucleus.
- Bacteria are prokaryotic cells.
- Plant cells and animal cells are eukaryotic cells.

Key Terms

prokaryotic cell
eukaryotic cell
photosynthesis
cellular respiration

TOPIC 1.4:

What interactions occur between humans and micro-organisms?

- A micro-organism is an organism that can only be seen with a microscope.
- Humans have both negative and postitive interactions with microbes.

Key Terms

micro-organism
microbe
pathogen

TOPIC 1.5:

How does the body protect us from pathogens?

- The immune system helps protect us from pathogens and infection.
- Outbreaks of disease can have an impact on populations.

Key Terms

immune system
inflammation

TOPIC 1.6:

What medicines help protect us from microbes that make us sick?

- Traditional First Peoples medicines and treatments come from resources in nature.
- Vaccines can help us prevent infections.
- Antibiotics can treat bacterial infections.

Key Terms

vaccine
antibiotic

UNIT 1

Review

What Do You Know?

Connecting to Concepts

Visualizing Ideas

1. Write a paragraph or use a T-chart to compare the parts and functions of a cell to one of the choices below.

Amusement park

School

Using Key Terms

2. Create a quiz-style game to assess understanding of these terms:

- cell theory
- cellular respiration
- eukaryotic
- immune system
- pathogen
- photosynthesis
- prokaryotic
- vaccine

Communicating Concepts

3. Explain how the human immune system defends your body against pathogens.
4. List the characteristics of living things, and given one example for each.
5. How does a unicellular differ from a multicellular organism?
6. Is a fallen, decomposing tree in a forest a living thing or a non-living thing? Use scientific understandings to justify your answer.
7. How can bacteria develop resistance to an antibiotic?
8. Describe the process of inflammation.
9. You sweat to remove heat from your body. What is another role of sweat?
10. Your mouth contains a thriving community of bacteria. Give four examples of relationships that bacteria have with humans.
11. What is a vaccine?
12. Think about the concepts you have learned about in this unit. Give at least three examples that show how you depend on energy from the Sun.
13. You have a sore throat from a viral disease. A friend suggests you get a prescription for an antibiotic. What would you say, and why?
14. Agree or disagree with this statement, and give your reasons: A pathogen is a microbe, but not all microbes are pathogens.
15. Many people mistakenly believe that plants perform photosynthesis but not cellular respiration. Explain how you know that plants must perform cellular respiration.
16. Would you expect to observe chloroplasts in the cells of the roots of a Columbia lily plant? Why or why not?

What Can You Do?
Connecting to Competencies

Developing Skills

17. The pharmacy section of a store has a fact sheet with the title "Use Antibiotics Safely." The fact sheet has three headings: Frequently Asked Questions, Read the Label, and Take Drugs Properly.

a) Write a brief paragraph of three or four sentences to go with each of these headings. Keep in mind that this is a fact sheet, so the information you write must be accurate and clearly expressed.

b) What extra information would you have liked in part a) of this question to help you develop your answer? Explain why you think this extra information would have helped.

18. Imagine your teacher asks you to work with three other students to design a scientific experiment to investigate the effects of a stimulus on a multicellular organism.

a) Create an outline that shows the steps of the inquiry process your group will follow.

b) Decide on an organism that you will use, and explain why you selected it as opposed to another organism.

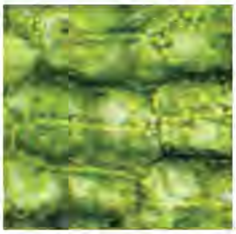
c) State a hypothesis for your experiment.

d) Write the steps of a procedure that you would follow to test your hypothesis.

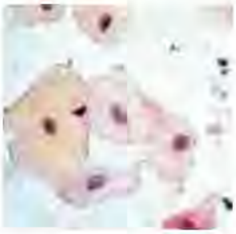
Thinking Critically and Creatively

19. Identify the type of cells shown in the photos of the microscope slides below. Demonstrate your understanding by providing some evidence as you explain your reasoning in each case.

a)



b)



20. In order to study micro-organisms, scientists face some unique challenges.

- They have to figure out how to grow the micro-organisms under artificial conditions in the laboratory.
- The very small size of micro-organisms means that they are not visible to the unaided eye.
- Many micro-organisms are dangerous and can be pathogens. Special precautions must be taken when working with them.

Use your scientific understanding to identify three things that you think scientists do to overcome these challenges.

21. What would happen to other organisms if most or all plant life disappeared? Explain your answer in terms of the life processes of cells and the life processes of multicellular organisms such as you and other animals.

22. Mitochondria are the organelles that enable a cell to carry out cellular respiration. Which do you think has more mitochondria: a skin cell or a muscle cell? Explain your reasoning.

Unit 1 Review *(continued)*

Understanding Big Ideas
Making New Connections

Applying Your Understanding

23. Reflect on what you have learned about factors that can help the immune system resist pathogens.

a) List at least three practices that you think you should adopt now to help improve the chances of your being and staying healthy as you continue on your life journey into adulthood.

b) Honestly evaluate the likelihood that you will adopt and maintain the practices you listed in part a) of this question. Explain why you think you will or won't adopt and maintain them. What are some challenges that you might face in adopting and implementing these practices?

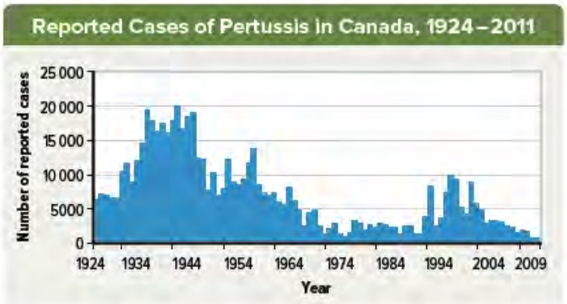
24. There is a lot of information about the health benefits of microbes in certain kinds of food products. One example is probiotics, which are microbes (mainly bacteria) found in foods such as yogurt, miso, sourdough, soft cheeses, and all kinds of pickles. The Internet is an especially rich source of this kind of information. Some of it is accurate, some is false, and some is misleading and/or incomplete.

a) How can you tell a reputable, reliable information source from one that is not? Use two examples to support your answer.

b) In what ways can misleading and/or incomplete information be harmful? Justify your opinion.

Thinking Critically and Creatively

25. Pertussis, also known as whooping cough, is a communicable disease in humans. It is caused by bacteria that affect the lungs, sending an infected person into bouts of intense, repeated coughing. The number of cases of pertussis that were reported in Canada between 1924 and 2011 is represented in the bar graph below. There is a vaccine for this disease.



Reported Cases of Pertussis in Canada, 1924–2011

a) Based on the graph, in what year do you think a vaccine became available in Canada? Explain how you arrived at your answer.

b) Scientists discovered that the vaccine that was given to children between the 1980s and 1997 was not very effective. In 2003 a booster vaccination was given to those affected. How is this reflected in the graph data?

26. Viruses have several uses in biotechnology and medicine. In many cases, the viruses are used as "vehicles" to deliver and insert specific materials into cells. The viruses are altered so that they should not be active or cause infection.

a) Why do you think viruses make good "delivery vehicles" of material to cells?

b) What could be a serious disadvantage of using viruses in this way? Explain your answer.

Connecting to Self and Society

27. You are a judge at an elementary school science fair. One student has made models to compare plant cells and animal cells. Develop a set of criteria to help you evaluate these models.

28. The researcher in the photo is collecting mosquito larvae in water that has collected in tires during an outbreak of West Nile Virus. This virus is carried by mosquitoes and very rarely causes a disease that is fatal.

One response to the risk of West Nile Virus is to spray pesticides in and around water sources that contain mosquitoes or in which they lay their eggs. Some of these pesticides can cause cancer. Outline your opinions of the pros and cons of this response. Consider social, ethical, and environmental implications of this response and your opinions of it.

29. The phrase "all my relations" is commonly used in connection with First Peoples ceremonies and practices. What does this phrase mean to you? Who are the relations that it acknowledges? What lessons can we learn from the meaning and significance of "all my relations?"

30. How can people with no science background beyond high school solve problems that baffle scientists? Ask the gamers who play Foldit, an online game for predicting the folded structure of protein molecules. Competing, as well as collaborating, a group of players took just three weeks to solve the structure of a protein called retroviral protease. HIV (the virus that leads to AIDS) uses this protein to reproduce. Knowing the structure can help scientists design new ways to keep the virus from replicating.

Games like Foldit cost a lot of money to code and keep online. And solving protein structures does not guarantee a successful disease treatment. Do you think spending money on games like Foldit is an effective way to help people who are sick? If not, how could the money be better spent? Use scientific understandings to support and justify your opinions.

31. Reflect on how this unit has helped you learn about yourself, about your community, and about ideas that interest you.

- What have you done, or what could you do, to make a difference at a personal level?
- What have you done, or what could you do, to make a difference in your community, province, or beyond?

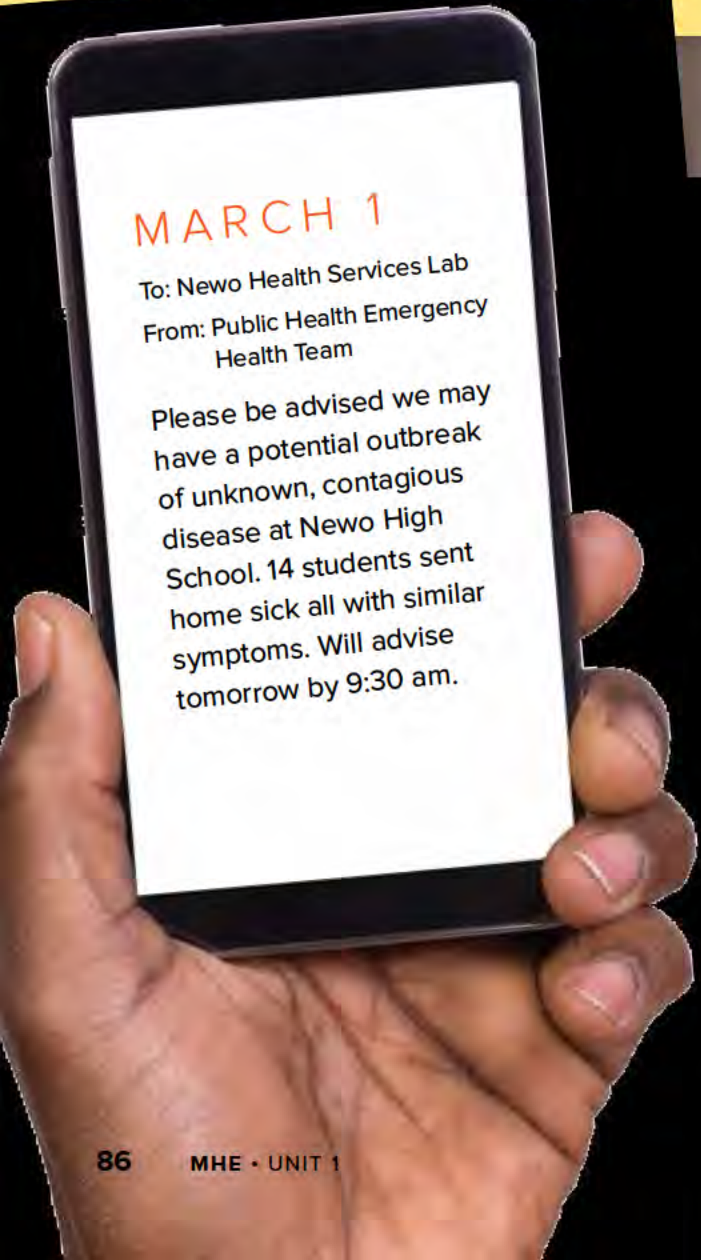
Share your own story in words, pictures, song, dance, or in another way you wish to communicate. Inspire yourself. Inspire others!

Unit Assessment

What's going on at Newo High School?

It started like most potential health emergencies begin. One person saw the school nurse because she was not feeling well. The nurse diagnosed the student with just an upset stomach. There was nothing to be concerned about for the rest of the students at Newo High School. But at lunch another four students arrived with similar symptoms, and by the last block of the day the number was up to fourteen.

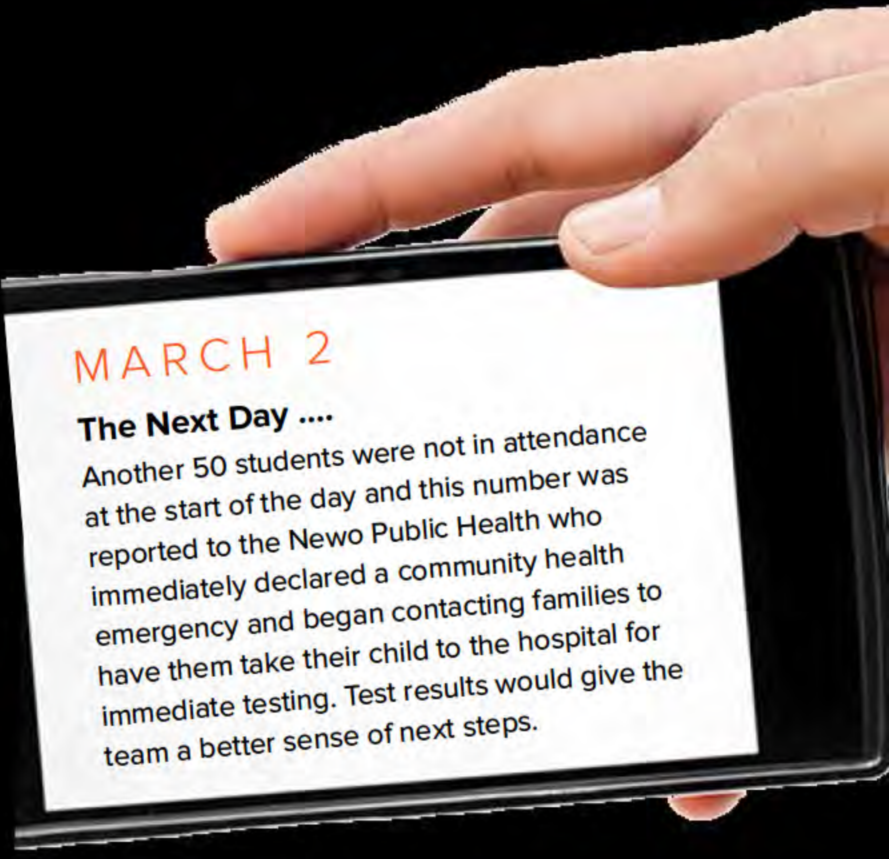
The school nurse was concerned and contacted public health officials. After a brief meeting of the public health emergency response team, a wait-and-see strategy was proposed. It was agreed to meet again the next morning after school attendance was taken.



MARCH 1

To: Newo Health Services Lab
From: Public Health Emergency
Health Team

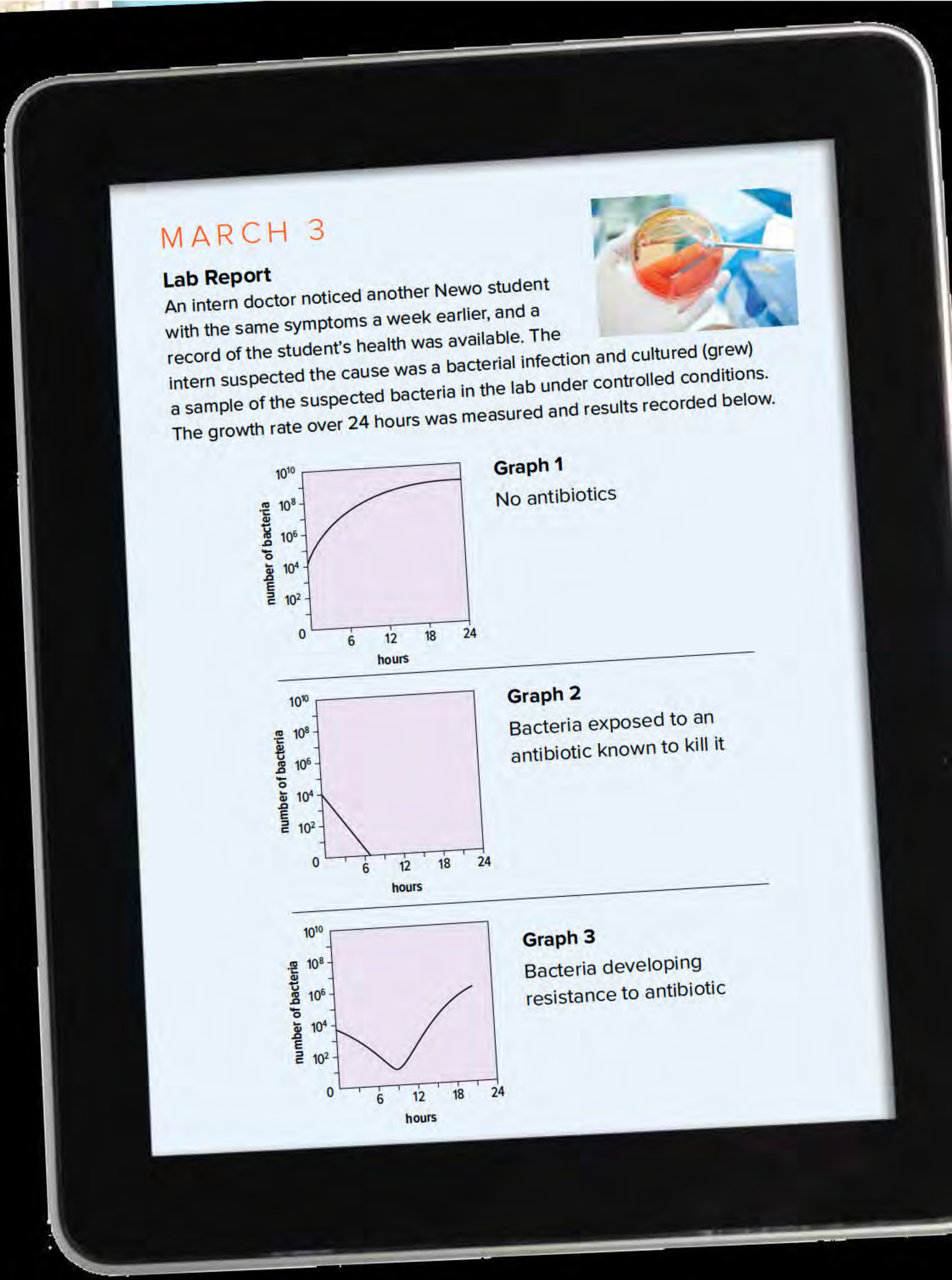
Please be advised we may have a potential outbreak of unknown, contagious disease at Newo High School. 14 students sent home sick all with similar symptoms. Will advise tomorrow by 9:30 am.



MARCH 2

The Next Day ....

Another 50 students were not in attendance at the start of the day and this number was reported to the Newo Public Health who immediately declared a community health emergency and began contacting families to have them take their child to the hospital for immediate testing. Test results would give the team a better sense of next steps.



MARCH 3

Lab Report

An intern doctor noticed another Newo student with the same symptoms a week earlier, and a record of the student's health was available. The intern suspected the cause was a bacterial infection and cultured (grew) a sample of the suspected bacteria in the lab under controlled conditions. The growth rate over 24 hours was measured and results recorded below.

Graph 1

No antibiotics

10^{10}
10^8
10^6
10^4
10^2
0
number of bacteria
6
12
18
24
hours

Graph 2

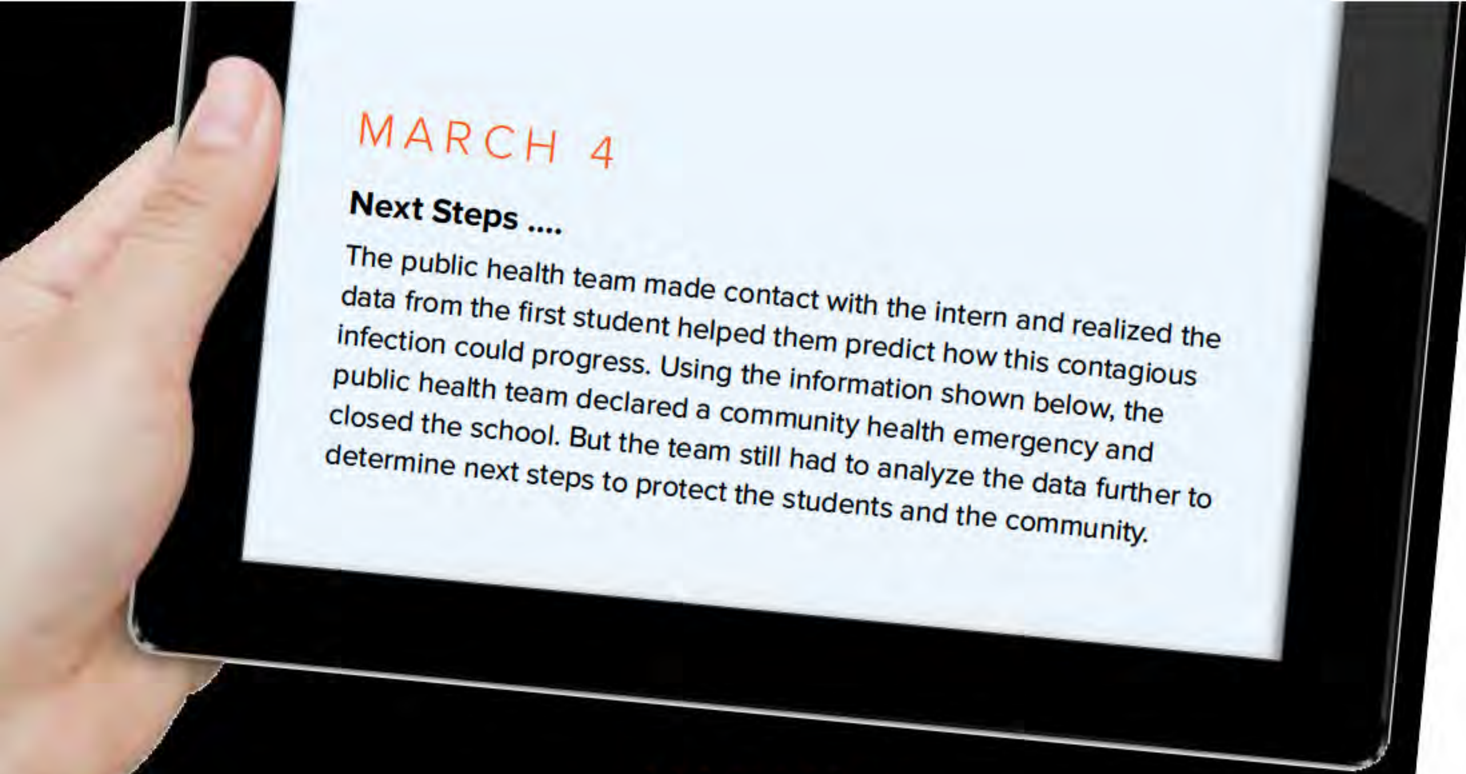
Bacteria exposed to an antibiotic known to kill it

10^{10}
10^8
10^6
10^4
10^2
0
number of bacteria
6
12
18
24
hours

Graph 3

Bacteria developing resistance to antibiotic

10^{10}
10^8
10^6
10^4
10^2
0
number of bacteria
6
12
18
24
hours

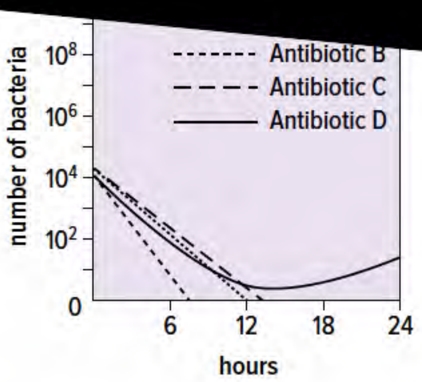


MARCH 4

Next Steps ....

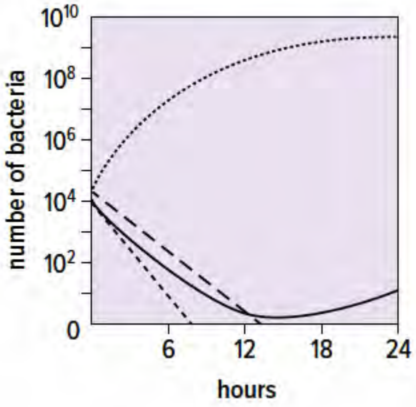
The public health team made contact with the intern and realized the data from the first student helped them predict how this contagious infection could progress. Using the information shown below, the public health team declared a community health emergency and closed the school. But the team still had to analyze the data further to determine next steps to protect the students and the community.

MARCH 5



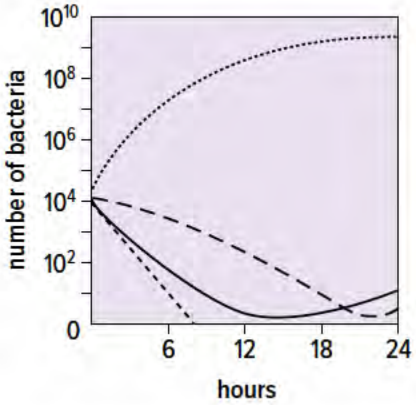
Day 1 (1 pm)

Arrival of Student X at the hospital. Samples taken for analysis



Day 2 (10 am)

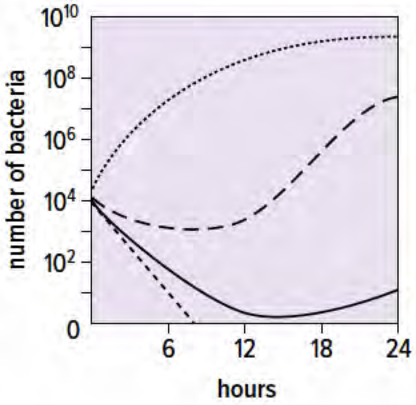
Student X's symptoms worsen. On return to hospital Student X prescribed a dose of antibiotic A.



Day 4 night (3 pm)

Student X is not getting better. Returns and is admitted to the hospital. Student X had been taking antibiotic A since Day 2 visit.

Doctors prescribe antibiotic C.



Day 5 (8 pm)

Student X spent Day 4 in hospital, having taken antibiotic A since Day 2 and antibiotic C since Day 4.

Your Task

Your teacher will start the TimeStamp™ video when the task begins. Based on the information from the intern's report, which antibiotic should be administered to all students to prevent infection from spreading throughout the school and community? Support your decision with evidence.

TOPIC 1.1

What are the characteristics of living things?

Key Concepts

- Living things are made of cells, take in nutrients, use energy, and produce waste.
- Living things respond to stimuli, grow, and reproduce.

Curricular Competencies

- Make observations aimed at identifying your own questions about the natural world.
- Consider Aboriginal perspectives and knowledge, other ways of knowing, and local knowledge as sources of information.
- Experience and interpret the local environment.
- Generate and introduce new or refined ideas when problem solving.

You, and most people, make distinctions between what is and is not a living thing. A tree is a living thing, but a building is not. A White Admiral butterfly, common throughout much of British Columbia, is alive, but a bulldozer is not. What is life?

Scientists usually do not try to define what "life" is. Instead, they describe features or characteristics that are shared by all living things. These characteristics of living things include their physical features, how they behave, and how they use matter and energy to support and sustain their lives.

Starting Points

Choose one, some, or all of the following to start your exploration of this topic.

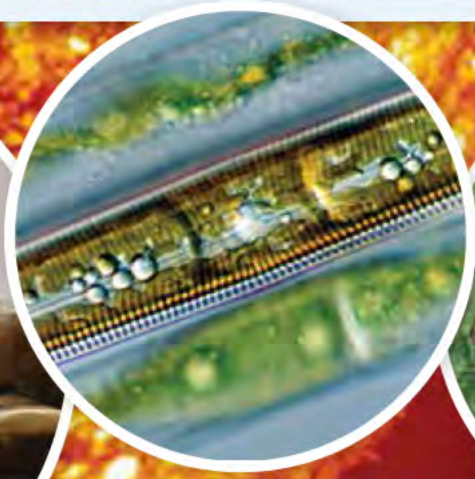
1. **Identifying Preconceptions** Examine the photos on these two pages. With the members of your group, brainstorm a list of characteristics that let you separate the living things from the non-living things. Compare your list with other groups. See if you can develop a class list of characteristics of life.
2. **Questioning** Some scientists search for life in our solar system and beyond. How will they know if they have found it? What characteristics do you think they should be looking for?
3. **Processing Information** Imaginary worlds abound on TV, in movies, in books, and in comics. These worlds are populated with all kinds of creatures. Choose a character from a show or story that you know, and list the characteristics that you think make it "alive." (Special challenge: How would your thinking change for a character in a story that features zombies or vampires?)

Key Terms

There is one key term that is highlighted in bold type in this Topic:

- cell

Flip through the pages of this Topic to find this term. Add it to your class Word Wall along with its meaning. Add other terms that you think are important and want to remember.



CONCEPT 1

Living things are made of cells, take in nutrients, use energy, and produce waste.

Activity

Hands-On with a Hand Lens

Obtain a hand lens and start observing objects in the places around you. For each, record and share what you see with and without the hand lens.

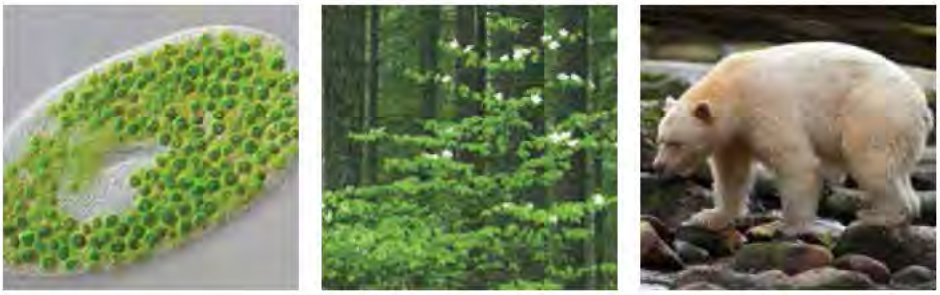
Why are ocean waves or rock formations considered to be non-living, but a bacterium and a plant are living? Throughout history, scientists have collected data and continued to define the characteristics of living things. Four of these characteristics are discussed below.

Living Things Are Made of Cells

All living things are made of one or more cells. Scientists consider the **cell** to be the basic unit of life. Cells have structures that enable them to carry out life processes. Life processes include all of the chemical reactions that help a living thing obtain and use energy, break down nutrients, build molecules, and grow. Life processes also enable a living thing to copy its genetic material, repair injuries, and excrete wastes.

cell the basic structural and functional unit of life

As shown in Figure 1.1, some living things are only one cell. Examples of single-celled or unicellular organisms are bacteria and some protists, such as *Euglena* and *Paramecium*. Figure 1.1 also shows multicellular organisms, which are made up of many cells. (The word "organism" means the same thing as "living thing.") You and many other living things are multicellular organisms.



Paramecium Pacific Dogwood Spirit Bear

Figure 1.1 Whether they are one-celled or many-celled, the cells of all organisms carry out life processes. What is the significance of the Spirit Bear to First Peoples? How do First Peoples use the Pacific Dogwood?

Living Things Take in Nutrients

All living things take in nutrients. These are substances that living things need but cannot make for themselves. Most organisms get the nutrients they need by eating food. Living things such as those shown in Figure 1.2 are consumers. They eat (consume) other organisms for food. Other kinds of living things, such as plants, are called producers, because they can produce their own food using the Sun's energy and nutrients from their surroundings.

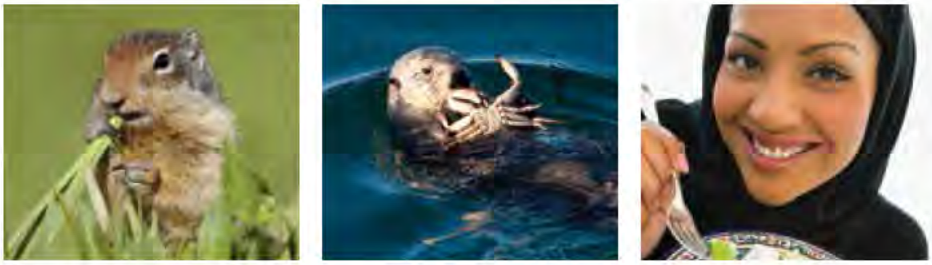


Figure 1.2 Squirrels, sea otters, and humans are all consumers. They get their nutrients from eating food. The grass the squirrel is eating is an example of a producer.

Living Things Use Energy

All living things use energy to carry out life proc
Producers use the food they make as a source of
get energy from the food they eat. The energy in
through a process called cellular respiration. Th
food is used for many purposes, such as growth,
changes in the environment, movement, and ev

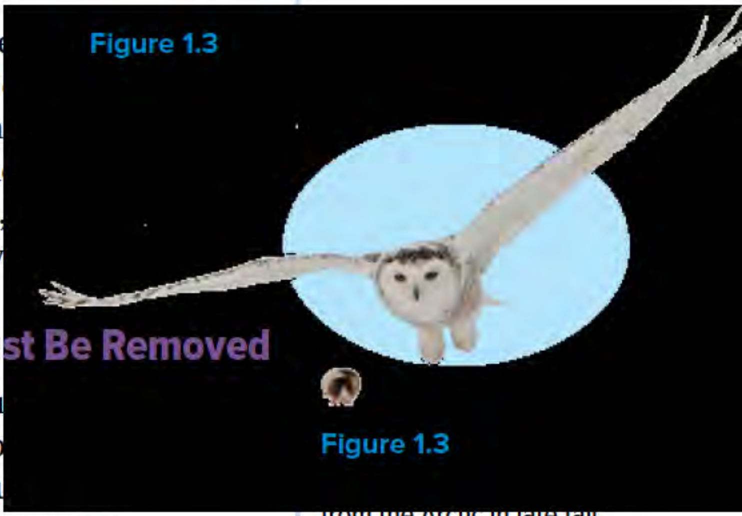


Figure 1.3

Figure 1.3

from the Arctic in late fall and winter. Mice are among its sources of food energy. Snowy owl is sacred to many First Peoples. What stories can you learn about snowy owl?

Living Things Produce Waste That Must Be Removed

Through their life processes, living things produ
substances that are harmful if they are not remo
structures that store and remove waste. Unicellu
have different ways to do this. For example, some waste passes naturally across the outer membrane of a cell into the surrounding environment. Other waste is expelled from the cell through a structure called a vesicle.

Multicellular organisms have structures or systems that collect and remove waste from the body. For example, humans have structures called kidneys that filter waste from the blood. The waste is removed from the body when a person urinates.

Before you leave this page . . .

1. How are unicellular and multicellular living things similar and different?
2. Why do living things need energy, and where do they get it?

CONCEPT 2

Living things respond to stimuli, grow, and reproduce.

Activity

Investigating the Characteristics of Life

Choose three organisms that you are familiar with in the places you live and visit. Explain how each organism has all of the characteristics of living things that you have explored so far.

Living Things Respond to Stimuli

A stimulus is anything that causes a living thing to react (respond) in a certain way. The plural of stimulus is stimuli. Living things respond to internal stimuli—things that occur inside their bodies. For example, when your stomach growls, you know you are hungry and you respond to this internal stimulus by eating. Feeling thirsty is another example of an internal stimulus. When animals, such as the caribou in **Figure 1.4**, are thirsty, they find water to drink.

Living things also respond to external stimuli—things that occur outside their bodies, in their surroundings. For example, if you have a dog or a cat, you may have seen its ears flick up in response to a noise at the door. The plant in **Figure 1.4** is responding to the light by growing toward it. Multicellular animals have sense organs and/or a nervous system to respond to stimuli. Unicellular organisms, such as *Euglena*, have structures that allow them to sense and respond to changes in their environment.

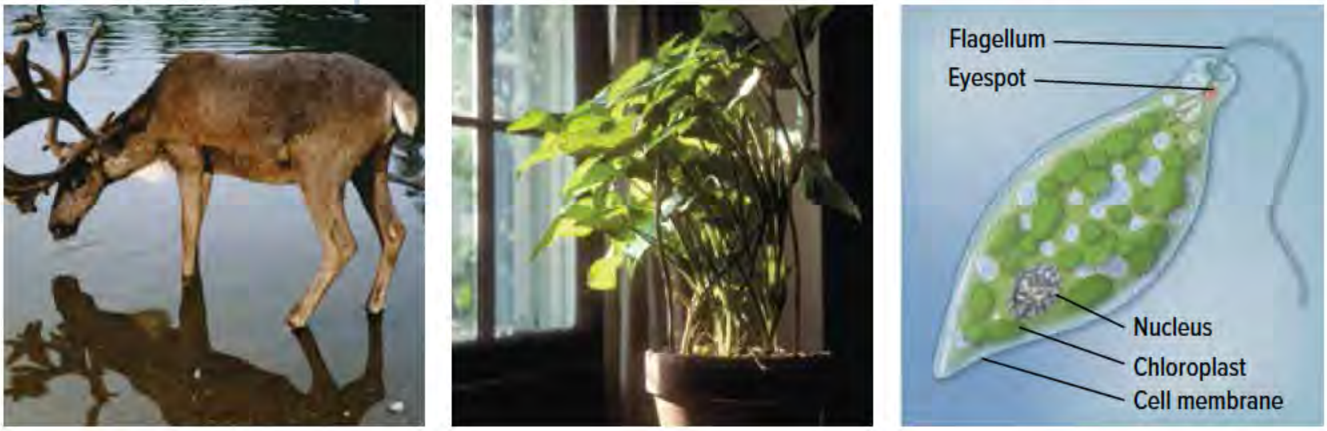


Figure 1.4 Organisms respond to internal and external stimuli. The caribou drinks in response to an internal stimulus. A plant growing toward the light is responding to an external stimulus. *Euglena* have a structure called an eyespot that allows them to sense the external stimulus of light.

Living Things Grow

All living things grow by increasing in size, or in the number of their cells, or both. Unicellular organisms grow by increasing in cell size, up to a certain point. Multicellular organisms grow by increasing the number of cells in their body.

Living Things Reproduce

All living things reproduce, which means that they produce more of their own kind (species). Organisms reproduce in different ways. Many unicellular organisms, such as the bacteria in **Figure 1.5**, reproduce by dividing into two cells. Each new cell is the same as the original cell, because it has the same genetic material. Other organisms must have a mate to reproduce. As shown in **Figure 1.5**, when organisms mate, their offspring are not identical to their parents. The offspring differ because each parent provides different genetic information.

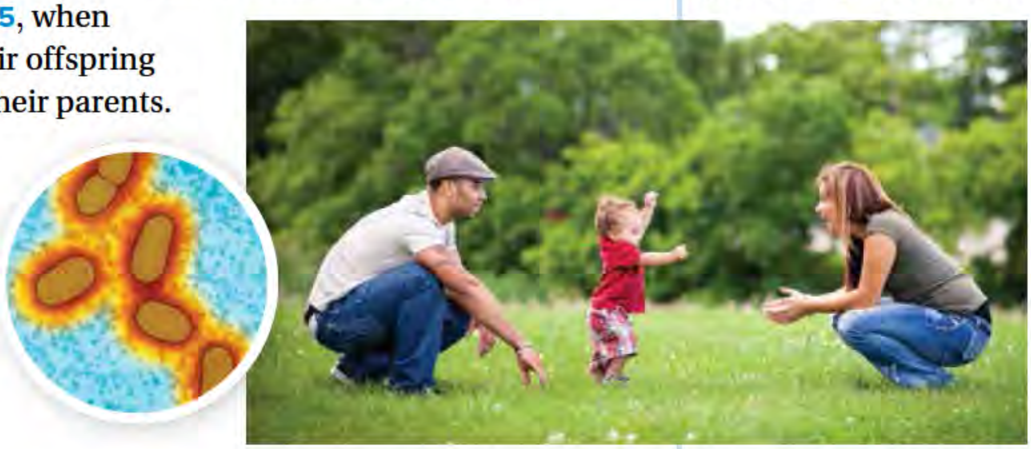


Figure 1.5 Some living things reproduce by dividing into two cells that are identical. Other organisms produce offspring with a mate.

Extending the Connections

Comparing How Different Peoples Define "Life"

Scientists have agreed on a set of characteristics to separate living and non-living things. However, science is just one of many different ways of knowing about and understanding ourselves and the world. Reflect on your own cultural background, and collaborate with your classmates to share the many ways that people think about and understand life.

Before you leave this page . . .

1. Create a scenario that includes six stimuli (three external and three internal). Your scenario must demonstrate your understanding without defining the words stimulus, external, and internal. Your scenario could take the form of a paragraph, a comic strip, a song, or another format of your choice.
2. Explain how growing is different from reproducing.

AT ISSUE How Does Artificial Intelligence Challenge Us to Think About Life?

What's the Issue?

Have you ever used a computer that recognizes and responds to your voice? Maybe you've played a computer game in which non-player characters act in very intelligent and realistic ways. Or perhaps you've heard of Asimo, a human-like robot that can challenge you to a game of soccer and even pour you a drink! These are all applications of artificial intelligence. Artificial intelligence (AI) is the science of creating intelligent machines. This definition may sound simple at first, but is it? For instance, what is intelligence? Can a machine be intelligent or capable of independent thought? Or is this a property only of living things?

People who work in AI write advanced computer programs that enable the machines they build to sense and respond to their environment. For example, some machines with AI can learn and solve problems. Some can recognize human speech and faces. Others can move and handle objects. These abilities are also a crucial part of a field that is closely linked to AI: robotics. Robots are becoming more advanced as scientists build upon their past successes. Will robots someday be able to carry out complicated jobs that only humans can do now? It's quite possible. If this happens, machines will likely lend a robotic hand in bringing it about.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. In 2011, an artificially intelligent computer named Watson played against and beat human players on the TV game show *Jeopardy*. Does knowing this change your opinion about what makes something living or not? Explain your reasoning.
2. Robots with artificial intelligence have some characteristics of living things. Which of the characteristics apply to robots? Do you think robots should be classified as living things? Why or why not?

Check Your Understanding of **Topic 1.1**

QP Questioning and Predicting   PC Planning and Conducting   PA Processing and Analyzing   E Evaluating
AI Applying and Innovating   C Communicating

Understanding Key Ideas

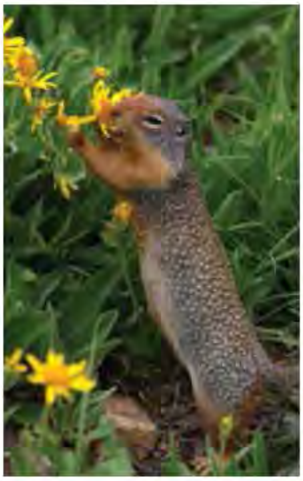
1. Choose an organism, and describe how it responds to one internal and one external stimulus. PA

2. Many non-living things have some of the same characteristics as living things. For example, a non-living thing might move, use energy, and grow in size. For each of the following, identify and describe the characteristics that it shares with living things. Then explain why scientists do not consider it to be living. PA E AI

- **a)** a campfire
- **b)** an icicle
- **c)** a printer
- **d)** a fossil

3. You are a multicellular organism. At this moment, there are millions of unicellular bacteria in and on your body. List five things that you have in common with a bacterium. PA C

4. The Columbian ground squirrel in the photo is a common sight in eastern B.C. Use this photo to describe the difference between an organism that is a consumer and an organism that is a producer. PA C



Connecting Ideas

5. Sundew plants grow in northern B.C. They make their own food like other plants do, but they also capture tiny insects with sticky droplets on their leaves. Nutrients from the rotting insects help the plant to grow. How would you classify a sundew: producer? consumer? something else? Explain your reasoning. E AI C

6. Scientists have defined several characteristics of living things. What evidence can you offer to demonstrate that your body displays the following characteristics? PA AI E

- **a)** Your cells are dividing.
- **b)** You respond to stimuli.
- **c)** You use energy to carry out life processes.

7. Scientists have agreed on the characteristics that they use to tell living from non-living. Why is it beneficial for scientists to use the same system and understandings when talking about living and non-living things? QP PA E C

Making New Connections

8. Imagine that you live in a future where robots take in nutrients, use energy, and produce waste. They also respond to stimuli. Each robot is made of artificial cells that can increase in number, allowing the robot to grow. Finally, the robots are able to reproduce by building new robots. Explain why you would or would not consider the robots to be living things. AI E C

TOPIC 1.2

Where do living things come from?

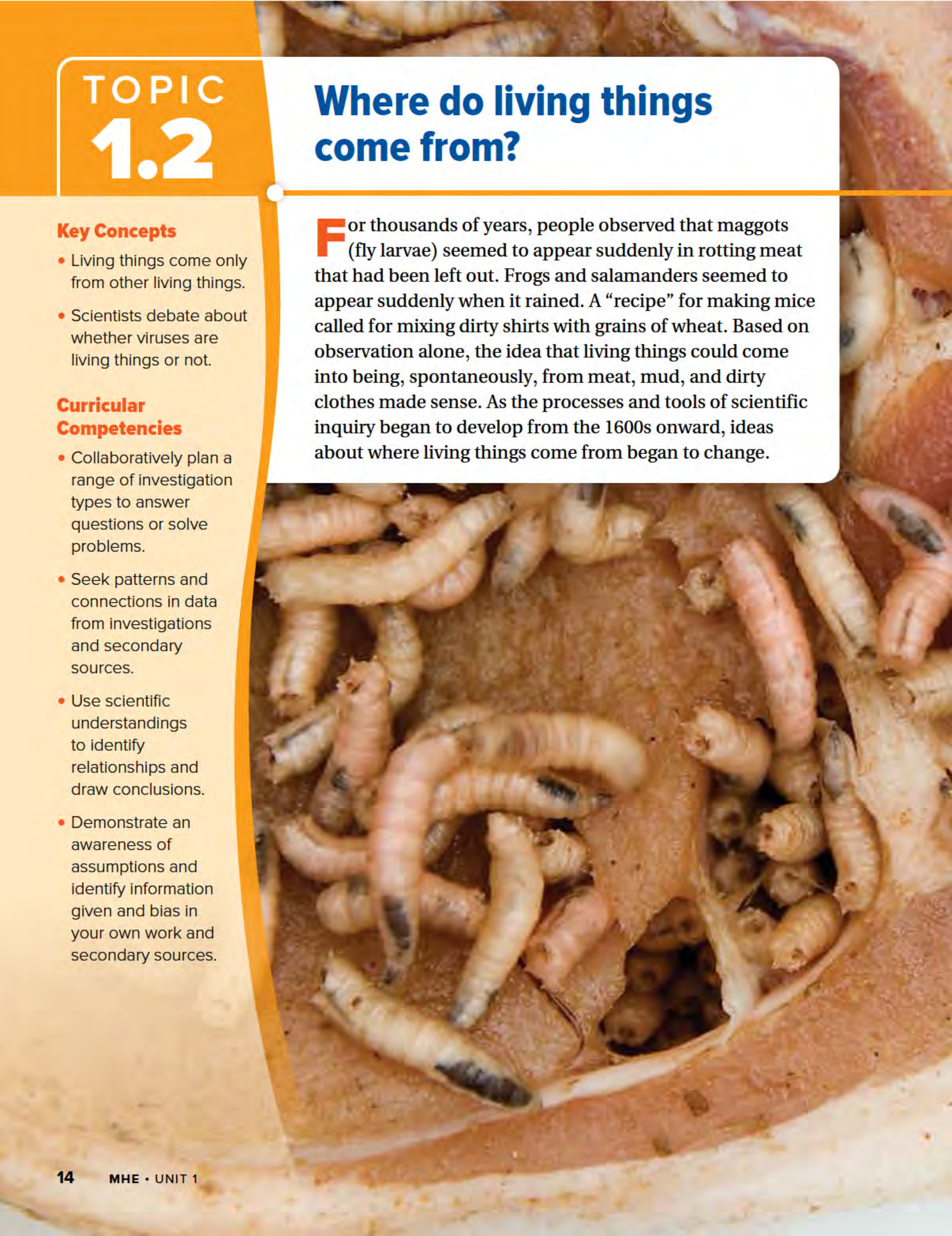
Key Concepts

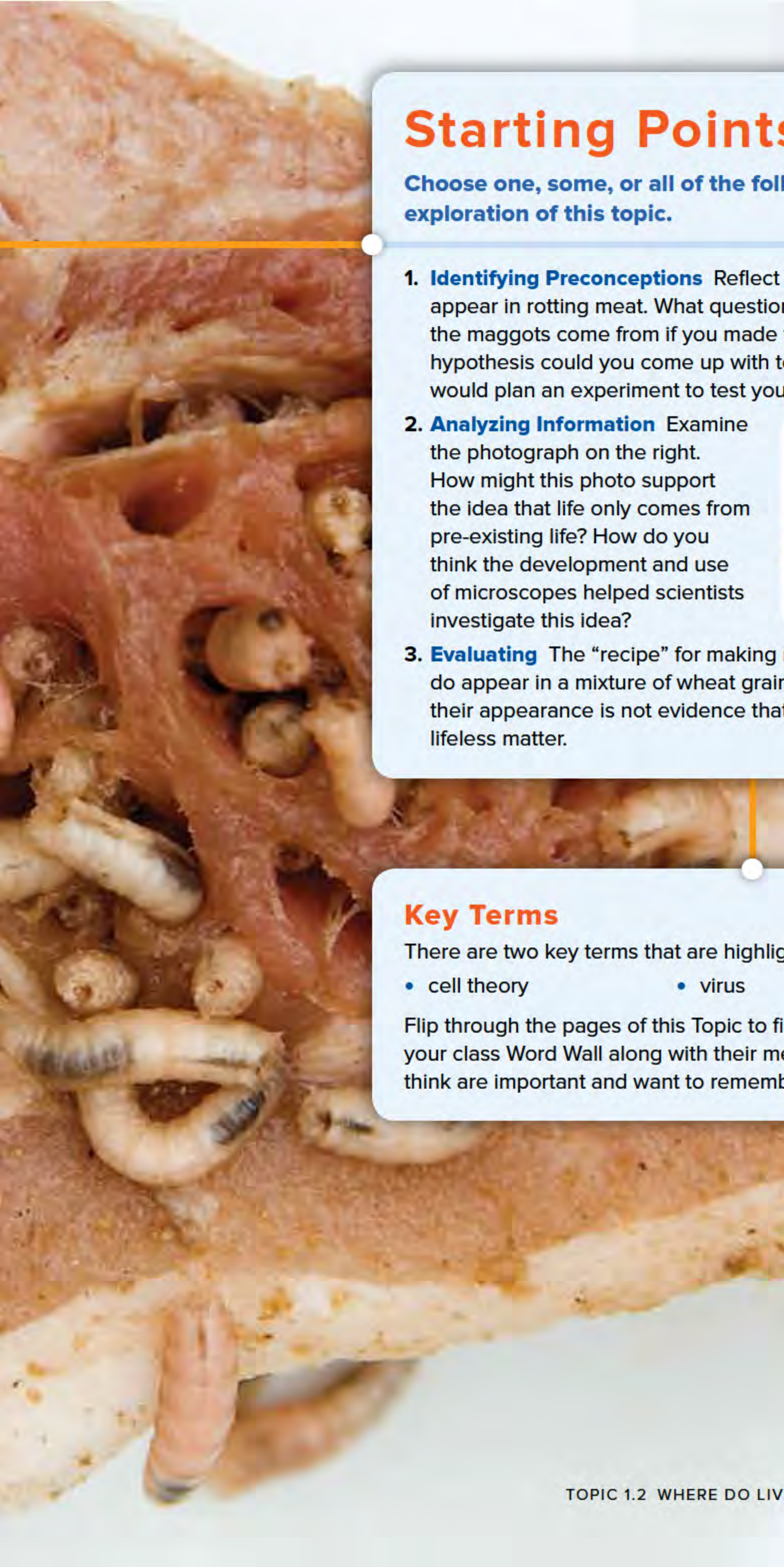
- Living things come only from other living things.
- Scientists debate about whether viruses are living things or not.

Curricular Competencies

- Collaboratively plan a range of investigation types to answer questions or solve problems.
- Seek patterns and connections in data from investigations and secondary sources.
- Use scientific understandings to identify relationships and draw conclusions.
- Demonstrate an awareness of assumptions and identify information given and bias in your own work and secondary sources.

For thousands of years, people observed that maggots (fly larvae) seemed to appear suddenly in rotting meat that had been left out. Frogs and salamanders seemed to appear suddenly when it rained. A "recipe" for making mice called for mixing dirty shirts with grains of wheat. Based on observation alone, the idea that living things could come into being, spontaneously, from meat, mud, and dirty clothes made sense. As the processes and tools of scientific inquiry began to develop from the 1600s onward, ideas about where living things come from began to change.

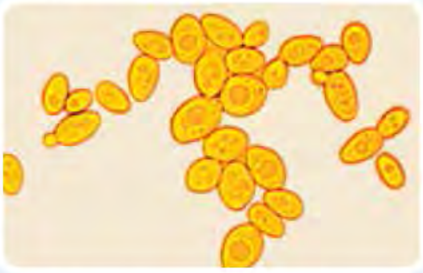




Starting Points

Choose one, some, or all of the following to start your exploration of this topic.

1. **Identifying Preconceptions** Reflect on the observation that maggots appear in rotting meat. What questions would you ask about where the maggots come from if you made this observation yourself? What hypothesis could you come up with to investigate it? Discuss how you would plan an experiment to test your hypothesis.
2. **Analyzing Information** Examine the photograph on the right. How might this photo support the idea that life only comes from pre-existing life? How do you think the development and use of microscopes helped scientists investigate this idea?



3. **Evaluating** The “recipe” for making mice seems to work. Mice often do appear in a mixture of wheat grains and a dirty shirt. Explain why their appearance is not evidence that living things can come from lifeless matter.

Key Terms

There are two key terms that are highlighted in bold type in this Topic:

- cell theory
- virus

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Living things come only from other living things.

Activity

Viewing Cells

Imagine you are a scientist more than 300 years ago and you make your own microscope. You look at a thin strip of bark from a cork oak tree and see the image shown in Figure 1.6. How would you describe these structures? What questions would you have after looking at the bark? How might you try to answer these questions?

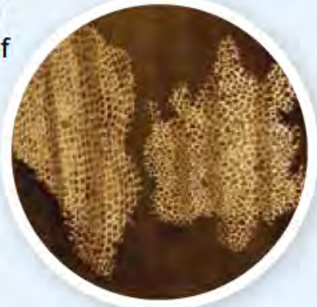


Figure 1.6 These are drawings that Robert Hooke made after viewing tree bark with the microscope that he designed.

Robert Hooke was a British scientist in the 17th century. In the 1660s, he created a microscope to observe tree bark. He called the structures that he saw cells, which is the term still used today to describe the structures that living things are made of. Around the same time, other scientists also made their own microscopes and observed single-celled organisms living in pond water (Figure 1.7). As technology for making microscopes improved, scientists were able to observe and learn more about different types of cells.

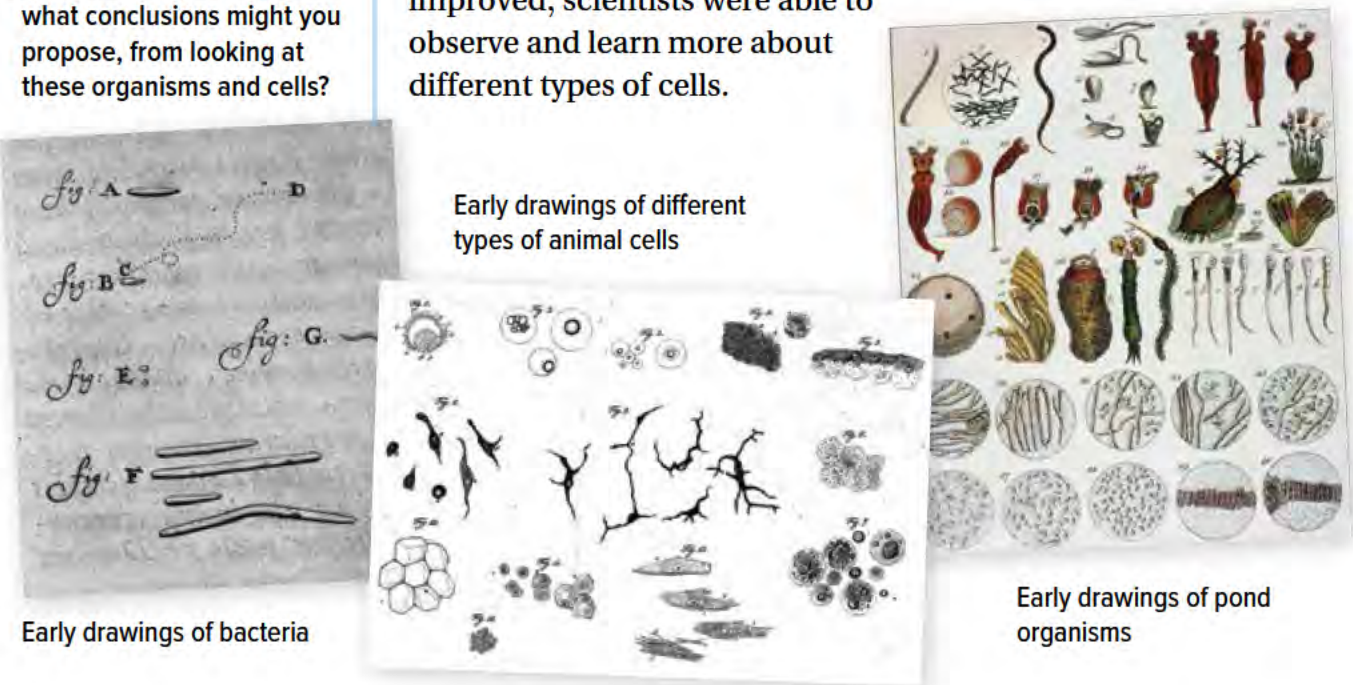


Figure 1.7 Drawings of different organisms and cells as seen under the microscope by scientists who were pioneers in this field. What ideas and questions do you have, and what conclusions might you propose, from looking at these organisms and cells?

Early drawings of bacteria

Early drawings of different types of animal cells

Early drawings of pond organisms

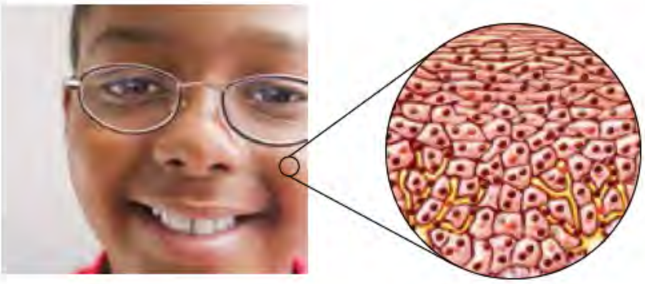
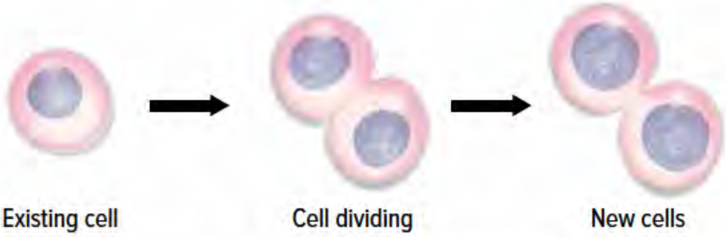
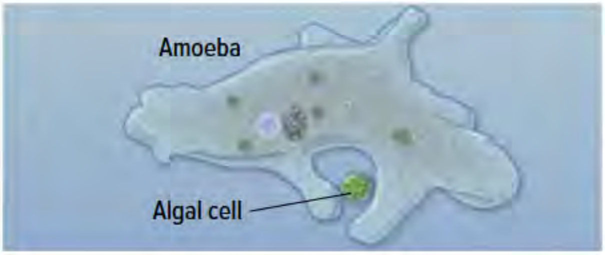
The Cell Theory

By the middle of the 1800s, scientists had made extensive observations of the cells of plants, animals, and other kinds of organisms. Based on the evidence they collected, scientists agreed on three important statements about cells and their connection with living things. These statements appear in Table 1.1. Taken together, these statements about cells are called the **cell theory**.

Connect to Investigation 1-A on pages 22–23

cell theory the theory in biology that explains the structure and source of all living things

Table 1.1 The Cell Theory

Statement	Example
All living things are made up of one or more cells.	
All new cells come from pre-existing cells.	
The cell is the basic unit of life.	This unicellular amoeba is surrounding an algal cell to get food and energy. 

Before you leave this page . . .

1. Identify the statements that make up the cell theory. Give an example that supports each statement.
2. What processes of scientific inquiry do you think scientists used to establish the cell theory?

CONCEPT 2

Scientists debate about whether viruses are living things or not.

Activity

Know-Want To Know-Learn (KWL) Chart

Use a KWL chart to organize the ideas you have about viruses. How many different viruses can you name? What roles do they play in ecosystems? How do viruses interact with humans and with other organisms? Record the answers to these questions or anything else you know or want to know about viruses. After you finish Concept 2, fill in the "What I Learned" column of your chart.

virus a strand of genetic material surrounded by a protein layer that can infect and reproduce in a host cell

A **virus** is a strand of genetic material surrounded by a layer of protein that can infect and reproduce in a host cell. Figure 1.8 shows the basic structure of a virus. The genetic material is surrounded by a protein coat. Some viruses have a tail-like structure and fibres. Others have a fatty membrane that surrounds the protein coat.

How Viruses Work

Viruses do not contain the cell parts that plant and animal cells do. So viruses cannot take in nutrients, use energy, or produce wastes like cells do. They cannot even reproduce on their own. Viruses must be inside the cell of another organism, called a host, to reproduce.

Before they enter a host, viruses are dormant (inactive). They cannot carry out any life functions. Viruses can exist in a dormant state for hours, days, and in some cases even months before they reach a host. For example, viruses that cause colds can stay dormant for up to 7 days on indoor surfaces. Viruses that cause the flu can stay dormant for 24 hours on a hard surface, such as a countertop. If these viruses do reach a host, they will use its cells to reproduce. That is all viruses do inside the host: reproduce.

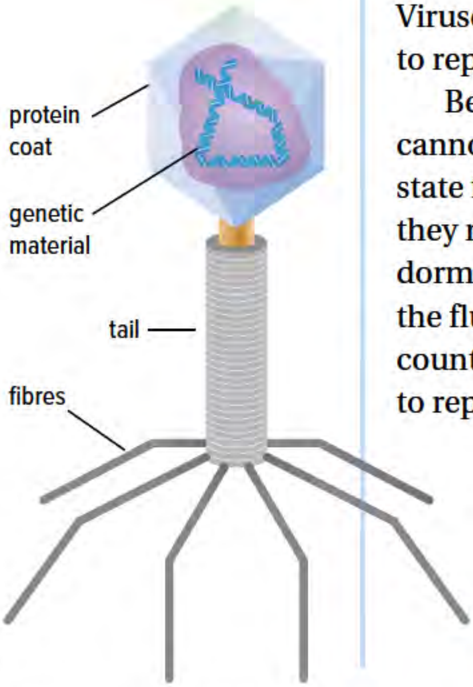


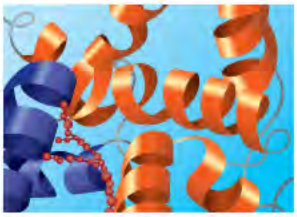
Figure 1.8 This is one type of virus called a bacteriophage. It infects bacteria.

How Recent Evidence Has Changed How Scientists View Viruses

Most scientists do not consider viruses to be alive, because they do not have the characteristics of living things. They cannot even reproduce without hijacking the structures and processes of host cells. However, in the last few decades, scientist have made discoveries that support the idea that viruses could be considered living things. The timeline in **Figure 1.9** describes some of these discoveries and what they mean.

Figure 1.9 The timeline shows some of the discoveries that provide evidence that viruses were once living things and may be more complex than previously thought.

2011: Scientists discover another large virus called the Megavirus. It has even more genetic material than Mimivirus. After comparing the genetic material of these two viruses, scientists believe that they may have evolved from a common ancestor that was able to make its own proteins.



1992–2008: Scientists discover and research the largest and most complex virus to date: the Mimivirus. It is up to 10 times as large as most viruses. It also has up to 5 times as much genetic material as other viruses. Some of the genetic material had never been seen before in viruses.

2015: Scientists trace the evolutionary history of more than 3000 viruses by comparing the folds in their proteins. Results show that more than 400 protein folds are shared between viruses and cells from other organisms and that 66 folds are unique to viruses. Based on these results, scientists infer that viruses once, long ago, had the same properties as cells. This could mean that viruses at some time in the past were alive and that they evolved as separate "organisms" at some later time.

Activity

Are Viruses Alive?

Hold a class debate on whether viruses are living things or not. Your teacher will assign your group to a position. Do research to prepare and strengthen your arguments. Then hold your debate. Afterwards, write a summary of your own opinion about whether viruses should be considered alive or not.

Before you leave this page . . .

1. Why do many scientists consider viruses to be non-living?
2. What new evidence is most convincing to you that viruses should be considered living things?
3. A number of fish farms raise salmon on the east and west coasts. A deadly flu virus that infects farm-raised salmon in the east is of concern in B.C. How could such a virus affect people and B.C. culturally and economically?

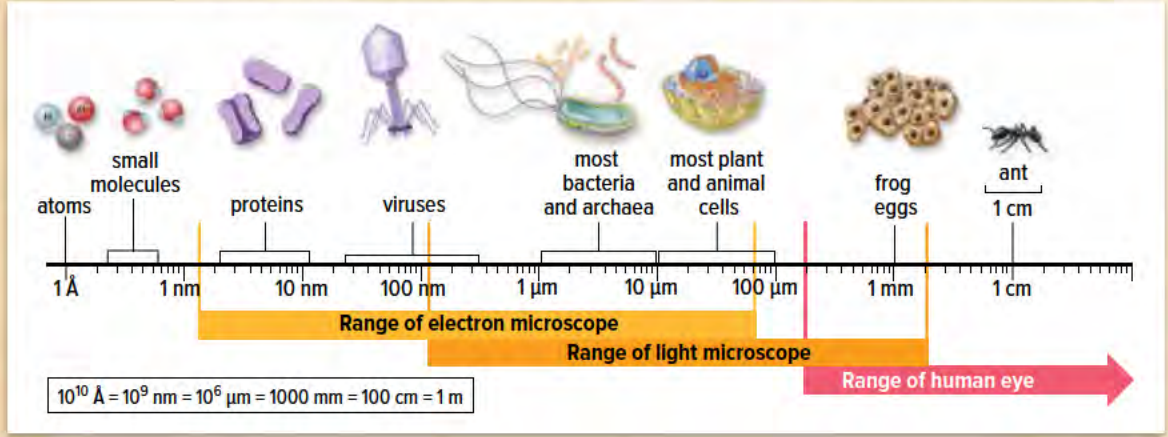
AT ISSUE

How can you visualize and compare the sizes of different objects?

What's the Issue?

The term *scale* refers to comparing objects by their size or by their amount. Look at the diagram below. Start at the left and focus your attention on the numbers. See that each segment in the scale represents 1/10 (one-tenth) of the length of the segment to its right.

In this diagram, pictures are used to help give a sense of the kinds of objects that are visible at different segments of the scale. The three coloured bars under the number scale show the range of sizes that are visible with the unaided eye, the light microscope, and the electron microscope. The kind of microscope that you use at school is a light microscope. The very powerful (and very expensive) kind of microscope used by researchers is an electron microscope.


atoms
small molecules
proteins
viruses
most bacteria and archaea
most plant and animal cells
frog eggs
ant
1 cm
1 Å
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
Range of electron microscope
Range of light microscope
Range of human eye
10^{10} Å = 10^9 nm = 10^6 µm = 1000 mm = 100 cm = 1 m

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. Microscopes like those you use at school have two lenses. An early, extremely powerful microscope used only a single lens. The person who invented it was an amateur, self-taught scientist. Investigate Antony van Leeuwenhoek to find out how he was able to see things in the late 1600s that scientists would not be able to see for another 150 years.
2. What kinds of light microscopes and electron microscopes are there? Why would you choose one kind of microscope over another for different kinds of research work?
3. The scale in the diagram compares objects only up to 1 cm in size. Find suitable objects to extend the scale farther—as far as you can. How cosmic can your sense of scale get?

Check Your Understanding of **Topic 1.2**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Record each statment of the cell theory, and explain what you understand each statement to mean. PA C

2. One of the scientists who contributed to the cell theory wrote: "Cells are the last link in a great chain [that forms] tissues, organs, systems, and individuals." PA E AI C
   - a) Which statement(s) of the cell theory are supported by this quotation?
   - b) The quotation continues: "Where a cell exists, there must have been...." What do you think the rest of the sentence says? Explain your answer using reasons that demonstrate a scientific understanding.

3. You are a science journalist writing for a popular online science magazine. Write a short article that explains
   - a) how recent evidence has changed the way scientists view viruses
   - b) why you think viruses should or should not be classified as living things

   PA AI E C

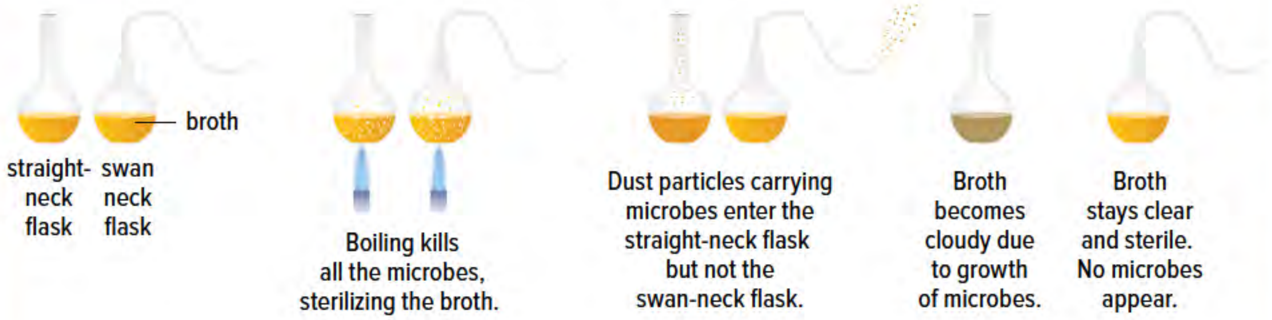
Connecting Ideas

4. A common way to diagnose a bacterial infection is to take a sample from a patient. Part of the sample is swabbed onto a jelly-like material in which the bacteria can grow. The material has nutrients such as sugars and minerals that the bacteria need to reproduce. Could this method be used to determine if an infection is due to a virus? Explain why or why not. PA AI

Making New Connections

5. Reflect on the paragraph used to introduce Topic 1.2. The idea that living things could come into being suddenly is called spontaneous generation. Louis Pasteur was one scientist who designed an experiment to disprove this idea. The diagram below summarizes the experiment. QP PA E C
   - a) Explain how it demonstrates that spontaneous generation cannot be correct.
   - b) How does the experiment provide support for the cell theory?

Use this diagram to answer question 5.


broth
straight-neck flask
swan neck flask
Boiling kills all the microbes, sterilizing the broth.
Dust particles carrying microbes enter the straight-neck flask but not the swan-neck flask.
Broth becomes cloudy due to growth of microbes.
Broth stays clear and sterile. No microbes appear.

INVESTIGATION
1-A

STRUCTURED INQUIRY

Using a Microscope to Look at Objects

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

What You Need

- Appendix A on page 364 (Care and Use of the Microscope)
- microscope
- microscope slide and cover slip
- forceps
- piece of thread
- piece of hair
- prepared slides provided by your teacher
- other objects to observe: for example, paper, pine needle, rice grain, cotton swab, piece of wool

In Appendix 1, you will have been introduced to the microscope—its parts, the proper way to use and care for this delicate piece of equipment, and some techniques for preparing materials to view them. Now, in this Investigation, you will use a microscope to observe different objects at different magnifications. This will allow you to practise and become comfortable using a microscope, which is an important skill that biologists use all the time.

Question

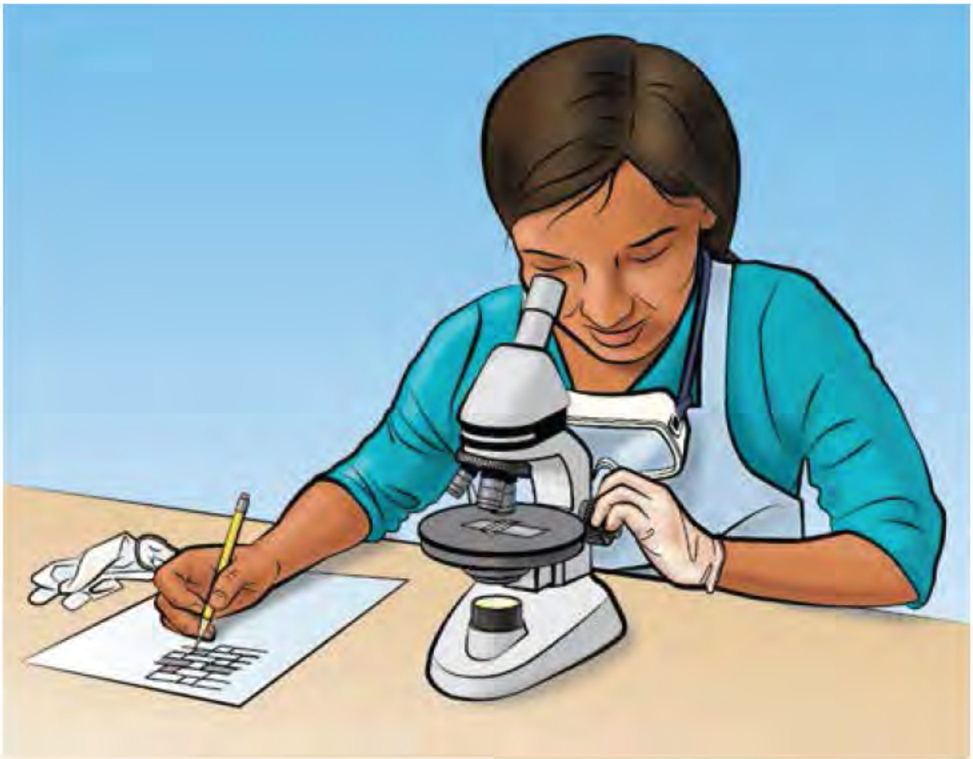
How can you build on your microscope experiences from Appendix 1 to observe an object?

Procedure

1. Obtain a microscope and set it up safely and properly at your work table.
2. Choose an object to observe.
3. Observe the object on low power. Make and label a sketch of the object.
4. Observe the same object on high power. Make and label a sketch of the object.
5. Repeat steps 2 through 4 with three other objects.
6. Clean up and put away the equipment you have used. Follow directions to safely dispose of materials.

Analyze and Interpret

1. Choose one of the objects you observed. Describe the differences you saw at low power and high power. How do your sketches reflect these differences?
2. Compare two similar objects, such as a piece of thread and a piece of hair, or a piece of cotton and a piece of wool. How are the objects similar? How are they different?

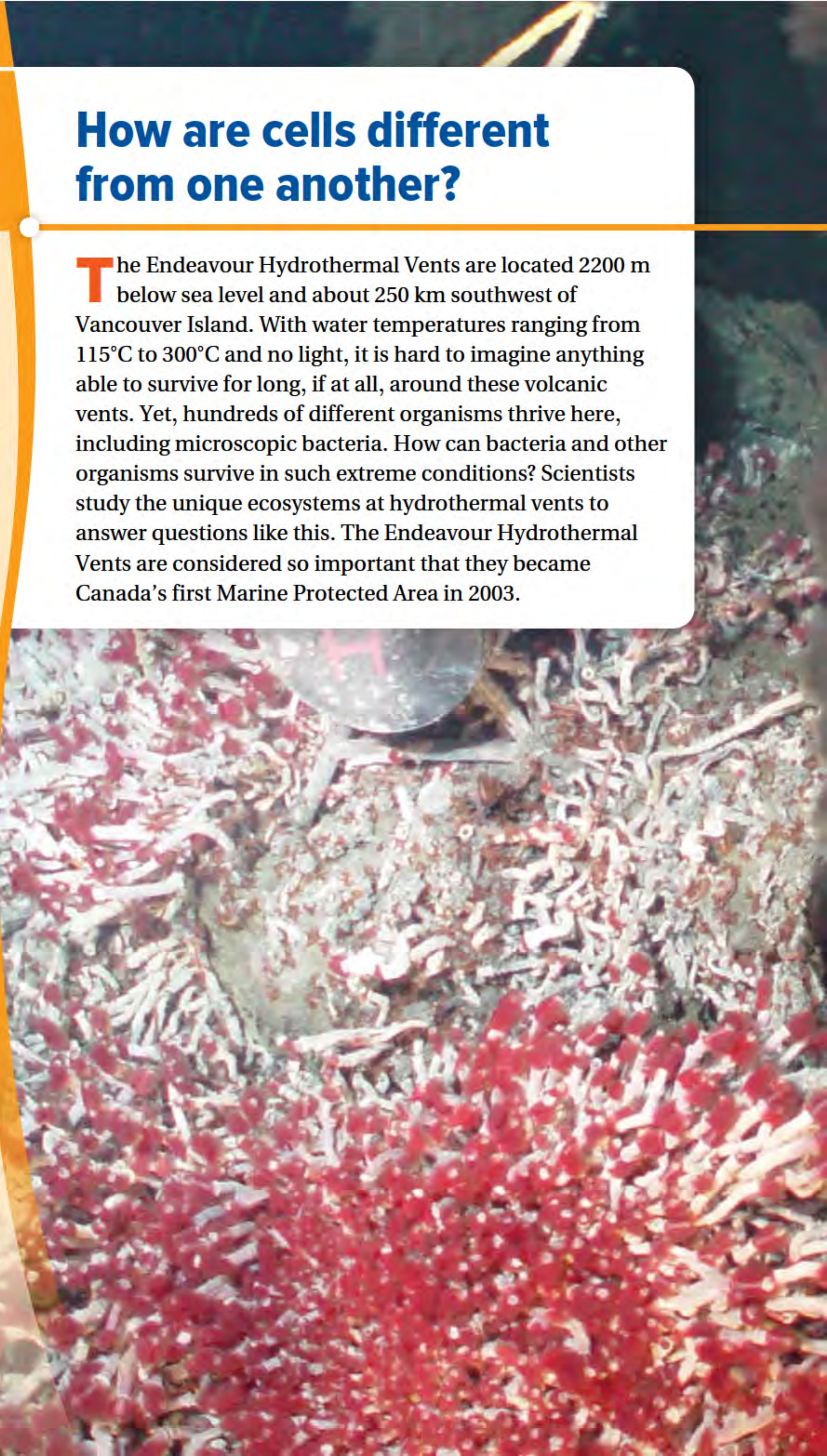


Conclude and Communicate

3. a) Share your sketches with your classmates. Can you identify what they were looking at based on the sketch? Did they notice things you didn't? Did you notice things they didn't?
   b) How can comparing your sketches with others help you to improve your skills?
4. Why is it important to accurately record your observations, whether you are making a drawing or making notes?
5. What are some sources of error in this Investigation? How might errors have affected your observations?

TOPIC 1.3

How are cells different from one another?



Key Concepts

- Scientists classify cells into two types based on the presence or absence of a nucleus.
- Bacteria are prokaryotic cells.
- Plant and animal cells are eukaryotic cells.

Curricular Competencies

- Measure and control variables through fair tests.
- Observe, measure, and record data with accuracy.
- Construct and use a range of methods to represent patterns or relationships in data.
- Reflect on investigation methods, including the adequacy of controls on variables and the quality of the data collected.
- Demonstrate an understanding and appreciation of evidence.

The Endeavour Hydrothermal Vents are located 2200 m below sea level and about 250 km southwest of Vancouver Island. With water temperatures ranging from 115°C to 300°C and no light, it is hard to imagine anything able to survive for long, if at all, around these volcanic vents. Yet, hundreds of different organisms thrive here, including microscopic bacteria. How can bacteria and other organisms survive in such extreme conditions? Scientists study the unique ecosystems at hydrothermal vents to answer questions like this. The Endeavour Hydrothermal Vents are considered so important that they became Canada's first Marine Protected Area in 2003.

Starting Points

Choose one, some, or all of the following to start your exploration of this topic.

1. **Identifying Preconceptions** Reflect on this statement: All cells have everything they need to carry out life processes. What does that statement mean to you? What are life processes, and what does a cell need to carry them out?
2. **Communicating** There are different types of extreme environments where you live, as well as in other places around the world. Describe three extreme environments that you have visited or know something about. What adaptations (features and behaviours) do you think different types of cells have to survive in these places?
3. **Analyzing Information** How is the shape of cells related to their functions in the human body? Look at some pictures of different kinds of cells—for example, skin cells, blood cells, and nerve cells. Why do you think they have the shapes they do?

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- prokaryotic cell
- photosynthesis
- eukaryotic cell
- cellular respiration

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Scientists classify cells into two types based on the presence or absence of a nucleus.

Activity

Asking Questions About Cells

As a scientist, you observe the two cells shown in Figure 1.10. Record at least three observations you can make. What questions can you ask based on your observations? What hypothesis would you state based on your observations and questions? How would you test your hypothesis?

As scientists have studied millions of cells, they have developed criteria that let them classify all cells into two main types. These two types—prokaryotic cells and eukaryotic cells—are compared in Figure 1.10.

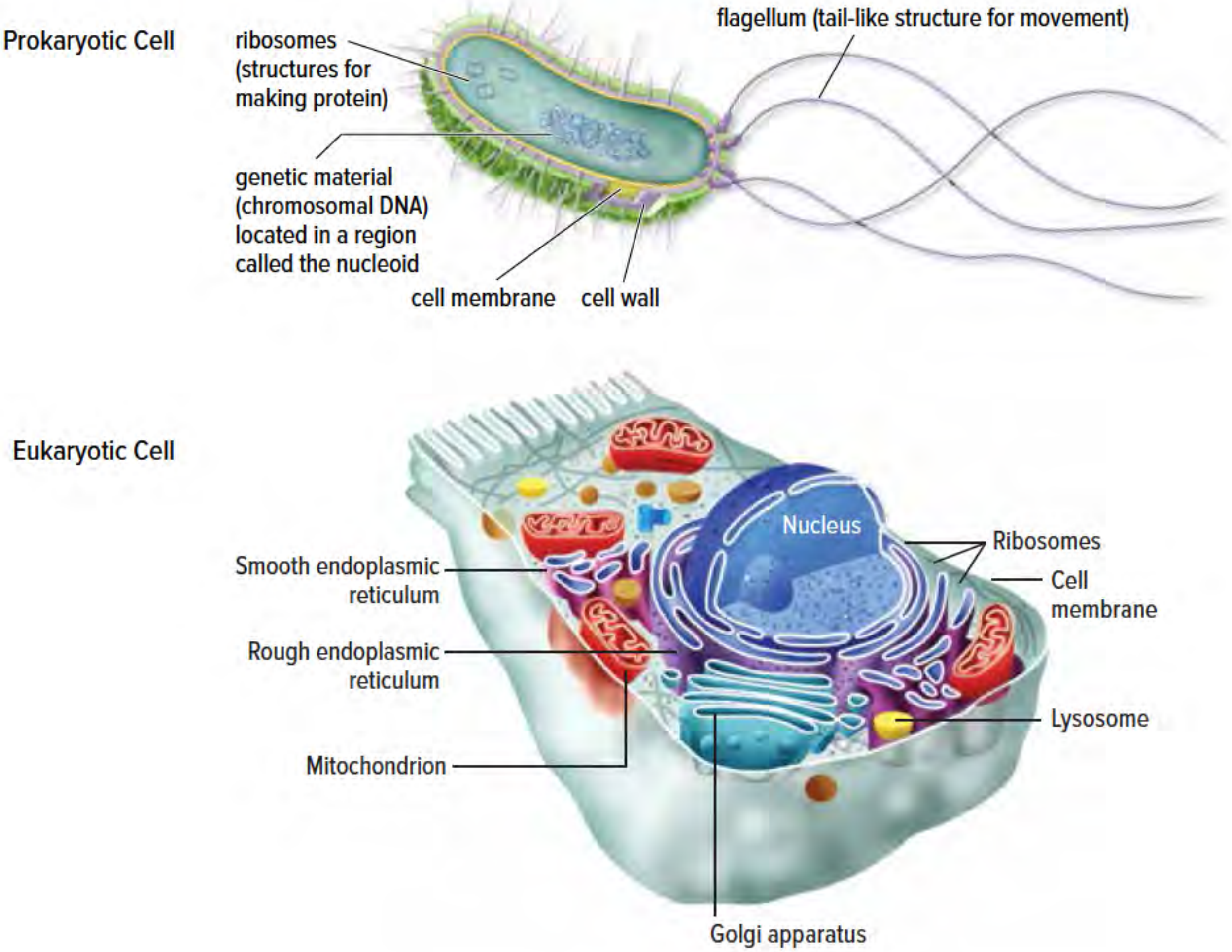

Prokaryotic Cell
ribosomes (structures for making protein)
flagellum (tail-like structure for movement)
genetic material (chromosomal DNA) located in a region called the nucleoid
cell membrane
cell wall
Eukaryotic Cell
Nucleus
Ribosomes
Cell membrane
Smooth endoplasmic reticulum
Rough endoplasmic reticulum
Mitochondrion
Lysosome
Golgi apparatus

Figure 1.10 The two main types of cells

Prokaryotic Cells

A **prokaryotic cell** does not have a separate nucleus. In fact, the word prokaryotic comes from the words *pro-*, which means before, and *karyon*, which means nucleus. In addition to lacking a nucleus, prokaryotic cells are simpler than the other type of cells. They have fewer internal structures.

prokaryotic cell a type of cell without a nucleus and whose internal parts are not surrounded by membranes

Eukaryotic Cells

A **eukaryotic cell** has a nucleus, which contains the cell's genetic material. The nucleus is surrounded by a membrane. The *eu-* part of the word means proper, so a eukaryotic cell is one that has a proper or actual nucleus. Eukaryotic cells also contain other internal structures called organelles, which carry out cell processes. Eukaryotic cells are about 10 times as large as prokaryotic cells, and they are more complex. Table 1.2 compares these two types of cells.

eukaryotic cell a type of cell whose nucleus and other internal parts are surrounded by membranes

Table 1.2 Comparison of Prokaryotic and Eukaryotic Cells

Characteristic	Prokaryotic Cell	Eukaryotic Cell
Genetic material contained in nucleus surrounded by a membrane	no	yes
Organelles surrounded by membranes	no	yes
Size and complexity	smaller and less complex	about 10 times as large and more complex
Can carry out all processes needed to stay alive	yes	yes
Example	bacterium	liver cell of an animal

Activity

Cell Models

Build a model of an organism that either is or contains prokaryotic or eukaryotic cells. Use materials you bring from home, those provided by your teacher, or computer software to make your model. How can you connect the components of your model to the processes of life?

Before you leave this page . . .

1. Use a Venn diagram to compare and contrast prokaryotic and eukaryotic cells.
2. Write three statements that are true of both prokaryotic and eukaryotic cells.

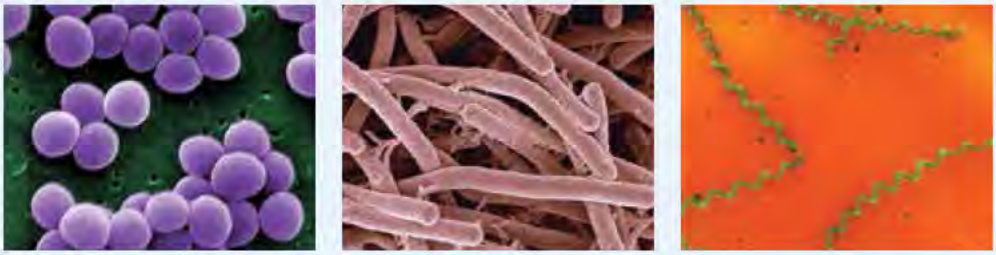
CONCEPT 2

Bacteria are prokaryotic cells.

Activity

Describing Bacteria

Observe the different types of bacteria cells shown below. How would you describe each cell? How are they similar? How are they different?



Could you live in boiling water or super–salty lakes? You could if you belonged to the archaea. These prokaryotic organisms live in extreme environments. You may be more familiar with the other group of prokaryotic organisms: bacteria.

Bacteria

A typical bacterial cell looks like the prokaryotic cell in **Figure 1.10** (on page 24). It has a cell wall and a cell membrane that surround its jelly-like cytoplasm. Genetic material and protein-making structures called ribosomes float within the cytoplasm. Some bacteria have whip-like flagella for movement.

Archaea

Like bacteria, archaea lack a nucleus and have a cell wall. But there are some important differences between them. Molecules found in archaea are more like the molecules found in eukaryotic cells than those of bacterial cells. Archaea also have molecules in their cytoplasm that are not found in any other type of organism.

Before you leave this page . . .

1. Make a T-chart to compare and contrast bacteria and archaea.
2. What new questions do you have about bacteria and archaea?

CONCEPT 3

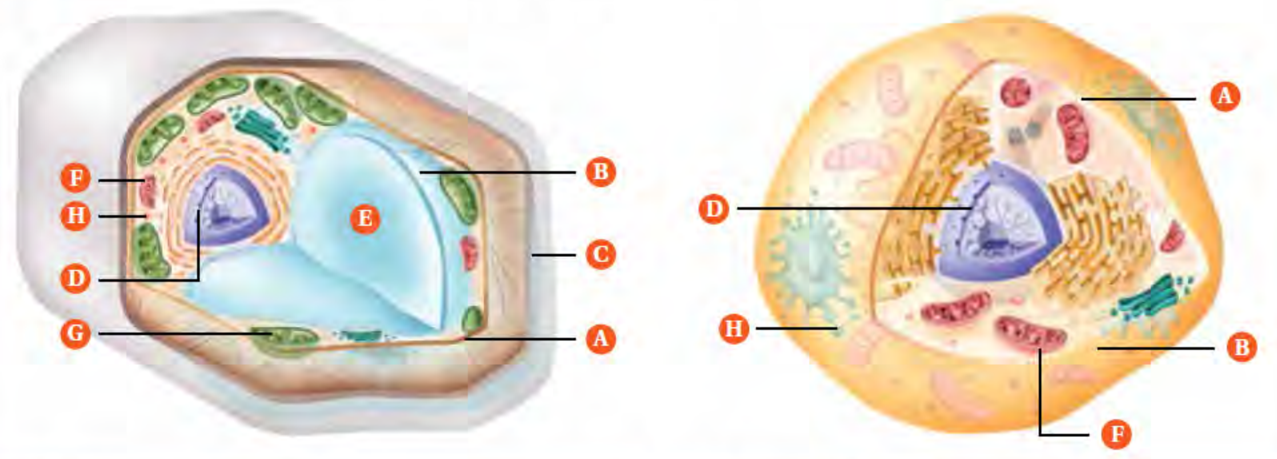
Plant and animal cells are eukaryotic cells.

Activity

Considering Plant and Animal Cells

Observe the plant and animal cells in Figure 1.11. Look at all the labelled features. Summarize the key similarities and differences.

Figure 1.11 shows the two main types of eukaryotic cells.



Cell Organelle	Structure and Function
A cell membrane	• surrounds and protects the contents of the cell • helps to control the movement of foods, wastes, and other substances into and out of the cell
B cytoplasm	• jelly-like fluid in which internal organelles float
C cell wall	• tough, rigid structure surrounding the cell membrane, giving plant cells a regular, box-like shape
D nucleus	• large, often round structure containing the genetic material that controls a cell's growth, reproduction, and other life-sustaining activities
E vacuoles	• balloon-like spaces within the cytoplasm to store wastes, food, and substances the cell cannot use right away • smaller and more numerous in animal cells
F mitochondria	• bean-shaped structures that release energy from food molecules to power cell processes
G chloroplasts	• structures containing chlorophyll (a green substance), which captures energy from the Sun to produce food (sugars) in the leaves and green stems of plants
H vesicles	• small sacs that transport materials and sometimes help materials enter and leave the cell

Figure 1.11 Some common organelles of plant and animal cells. Organelles help cells carry out their life processes.

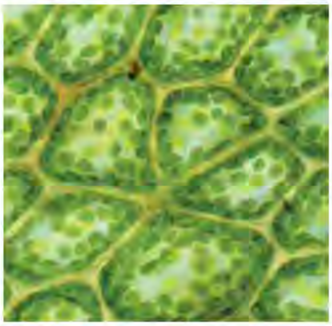


Figure 1.12 Chloroplasts are green-coloured structures in plant cells.

Plant Cells

Plant cells have organelles that carry out all of the processes needed for the whole plant to survive. Plant cells also have some structures that animal cells don't. Plant cells have thick, rigid cell walls to provide support. They also have a large vacuole, which is a structure that stores water and other substances.

Plant cells have a type of organelle that animal cells do not: the chloroplast. Chloroplasts, like the ones shown in Figure 1.12, capture the energy in sunlight. This energy is needed to power a process that takes place in chloroplasts: photosynthesis.

Photosynthesis

photosynthesis a chemical reaction in the cells of plants that converts the Sun's light energy into chemical energy that organisms can use

Photosynthesis is a chemical reaction that uses the energy of sunlight to change carbon dioxide and water into sugar and oxygen. As shown in Figure 1.13, plants take in carbon dioxide from the air and absorb water through their roots. Light energy comes from the Sun. Plants need the sugar produced by photosynthesis for use as food. The oxygen is a waste by-product that is released into the air.

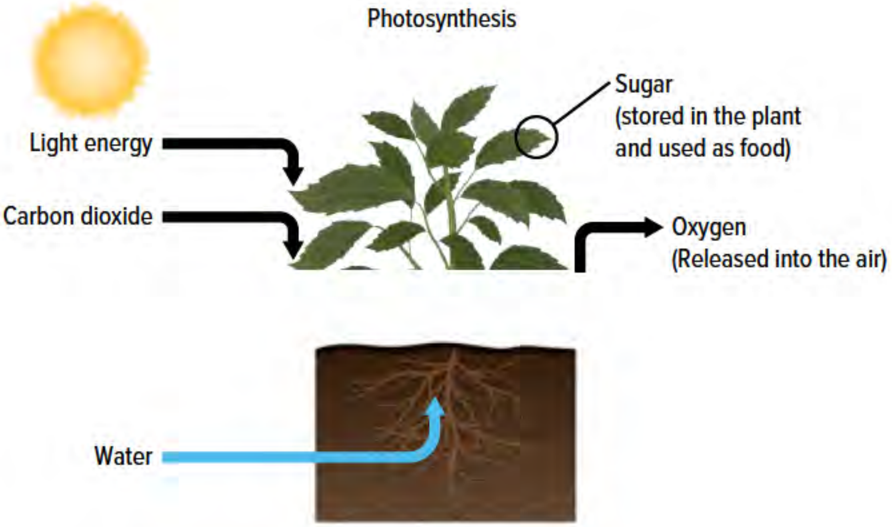

Photosynthesis
Light energy
Carbon dioxide
Sugar (stored in the plant and used as food)
Oxygen (Released into the air)
Water

Figure 1.13 Photosynthesis converts the energy of sunlight into chemical energy (in the form of sugar).

Animal Cells

Animal cells have organelles that carry out all of the processes needed for the whole animal to survive. Animal cells have a cell membrane that controls the movement of substances into and out of a cell. Vesicles break down waste materials, which may be recycled or moved out of the cell.

In plant and animal cells, the nucleus directs cell activities and contains genetic material for reproduction. Plant and animal cells also have mitochondria. These organelles play a key role in another important life process called cellular respiration.

Connect to Investigation 1-B on Pages 34–35

Connect to Investigation 1-C on pages 36–37

Cellular Respiration

Cellular respiration is a chemical reaction in which sugar and oxygen in cells are changed into carbon dioxide and water. As part of this reaction, energy is released. The energy produced from cellular respiration is used by organisms to carry out life functions. Carbon dioxide and water are waste by-products.

cellular respiration a chemical reaction in the cells of most organisms that releases the energy needed to carry out life processes

Photosynthesis and Cellular Respiration

Figure 1.14 shows the relationship between photosynthesis and cellular respiration. These two processes function together as part of an important cycle. Most living things depend on this cycle to survive.

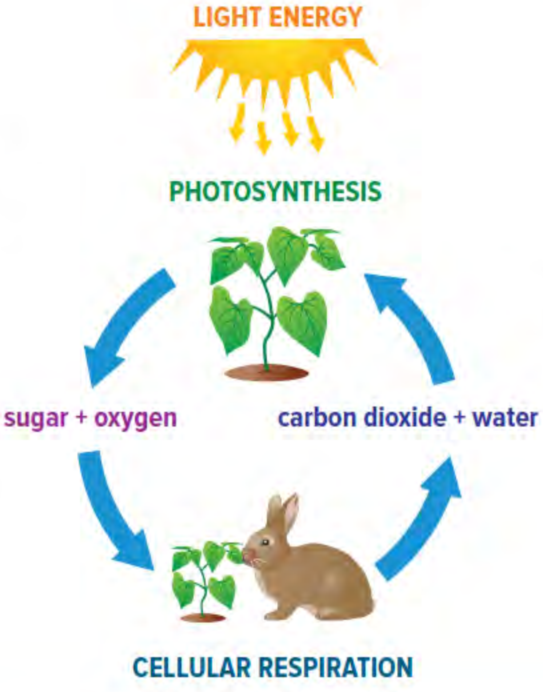


Figure 1.14 Photosynthesis stores energy, and cellular respiration releases energy. As well, each process makes the raw materials that the other process needs to store or release energy.

Plants and other organisms use the carbon dioxide and water produced by cellular respiration as part of photosynthesis.

Plants, animals, and other organisms use the sugar and oxygen produced by photosynthesis as part of cellular respiration.

Before you leave this page . . .

1. Identify and describe the key similarities and differences of plant and animal cells.
2. Explain how chloroplasts are related to cellular processes.
3. Some people describe photosynthesis and cellular respiration as the reverse of each other. Use well-reasoned arguments to explain why you agree or disagree with this idea.

AT ISSUE How does excess carbon dioxide affect plants?

What's the Issue?

The amount of carbon dioxide in Earth's atmosphere has increased more than 70% since the early part of the 18th century. This gas is a key driver of climate change. But since plants need carbon dioxide, you might wonder if they gain any benefit—how does excess carbon dioxide affect plants?

Studies show that plants grown in air with more carbon dioxide have higher rates of photosynthesis and increased growth. But carbon dioxide is just one factor. Plants need other things to grow, such as light, water, nutrients, and space. It turns out that plants will increase in growth in response to extra carbon dioxide, but only until they cannot get enough of one or more of the other factors they need. The lack of a critical factor will then limit their growth.

Growth is not the only issue, though. In response to more carbon dioxide, plants absorb *less* nitrogen. This nutrient is a key part of proteins. Studies conducted on crops, grasslands, and forests all showed that plants had less protein after growing in conditions of increased carbon dioxide.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Some of the studies described in the At Issue section have been done in laboratory settings, and others have been carried out in natural settings.
   a) What are some advantages and disadvantages of carrying out an experiment in each type of setting?
   b) What kinds of differences do you think there are in planning and conducting experiments in these two settings?
   c) How might those differences affect results and how results are processed and analyzed?
2. Much of the world's population relies directly and indirectly on proteins from plants, such as wheat, rice, and corn (maize). How might a decrease in plant protein affect our ability to feed ourselves?
3. Plants are producers in most ecosystems. How do you think ecosystems could change in response to excess carbon dioxide?
4. What questions do you have about the information in the At Issue section? (For example, what do you think "studies" could mean?) How could you find answers to your questions?

Check Your Understanding of **Topic 1.3**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Describe the basic function of the following organelles. PA
   - **a)** the nucleus
   - **b)** the cell membrane
   - **c)** the cell wall
   - **d)** mitochondria
   - **e)** chloroplasts
   - **f)** vacuoles

2. Imagine that scientists discover a new unicellular organism in the Lakelse Hot Springs near Terrace. Its characteristics are described below. Decide whether the microbe is more likely to be a type of bacteria or archaea. Explain how you made your decision. PA C
   - It has a cell wall.
   - It has no nucleus.
   - Some of its molecules are similar to molecules found in eukaryotic cells.
   - Some of its molecules are not found in any other type of organism.

3. Scientists often compare organisms in terms of their complexity. In other words, some living things are considered to be simple and others are considered to be more complex. This idea of complexity refers to the structures and functions of the organisms. QP PA AI C
   - **a)** Justify the following statement: Eukaryotic cells are more complex than prokaryotic cells.
   - **b)** Reflect on the kinds of organisms that are made up of these two types of cells. Then explain why your answer to part a) is sensible.

4. A meteorite strikes Earth. Photosynthesis is reduced by 50% due to the release of dust into the atmosphere. Predict what will happen to animal life. Explain your answer in terms of cellular processes. QP PA AI

5. As you study a cell under a microscope, you observe a nucleus and a large vacuole. What features would you look for to decide what type of cell this is? Explain your reasoning. QP E

Connecting Ideas

6. Write a script for a skit in which four people act out the processes of photosynthesis and cellular respiration. PA AI C

7. As we search for signs of life on other planets, do you think we are more likely to find prokaryotic or eukaryotic forms of life? Justify your opinion. QP AI C

Making New Connections

8. One of the things western science does well is explain the microscopic parts (such as cells and atoms) that make up the world. One of the things the Traditional Ecological Knowledge (TEK) of First Peoples does well is explain how all living things are connected with one another, this world, and all other worlds. In this Topic, you learned about microscopic cells. You also learned about a cycle that connects and sustains life on Earth. Write a conversation between two characters, West-Sci and TEK, who are trying to develop a better understanding of each other's view of life and the world. QP PA E AI C

INVESTIGATION

1-B

STRUCTURED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

What You Need

- microscope
- prepared slide of plant cells
- prepared slide of animal cells

How are plant cells and animal cells similar and how are they different?

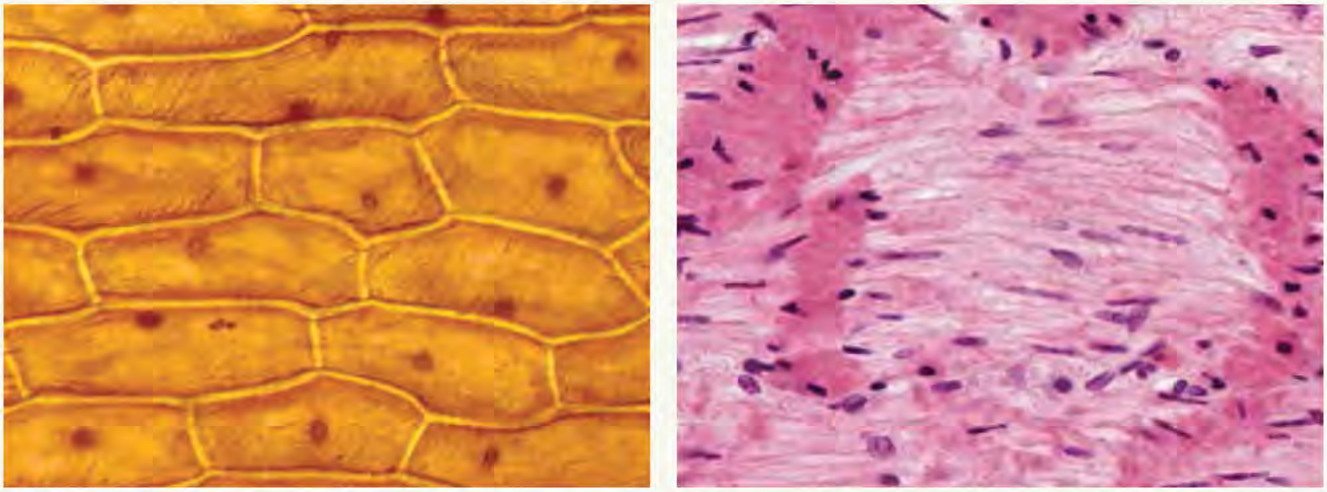
A light microscope enables you to observe many of the structures in cells. Increasing the magnification means you see a smaller portion of the object, but lets you see more detail. As you see more details, you are better able to compare and contrast different cell types.

Question

How can you compare and contrast plant cells and animal cells?

Procedure

1. Use a microscope to observe the plant cells on low power. Focus on the top layer of cells.
2. Switch to high power and focus on one cell. The large organelle in the centre of the cell is the central vacuole. Surrounding the central vacuole are green, disc-like objects called chloroplasts. Try to find the nucleus. It looks like a clear ball.
3. Draw a diagram of one plant cell. Label the cell wall, central vacuole, chloroplasts, cytoplasm, and nucleus. Return to low power and remove the slide. Return it to your teacher, or place it where it is safe.
4. Observe the animal cells under low power.
5. Switch to high power and focus on one cell. Draw a diagram of one animal cell. Label the cell membrane, cytoplasm, and nucleus. Return to low power and remove the slide.



These images show a typical plant cell and animal cell as viewed with a light microscope. How do they compare with what you observe in class? Which organelles do you recognize?

Process and Analyze

1. Based on your diagrams, how do the shapes of the two types of cells compare?
2. Compare and contrast the cell structures in your two diagrams. Which structures did you observe in both cells? Which structures did you observe in only one of the cells?

Conclude and Communicate

3. Share your drawings with your classmates. How do their drawings differ from yours? Are they more accurate? Do they have more detail? Explain your answers.
4. How could you improve your drawings? Why is it important that drawings of observations be made as clearly and accurately as possible?

INVESTIGATION

1-C

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

What You Need

- test tube
- leaf from aquatic plant (e.g., *E. canadensis* or similar)
- scissors
- beaker
- water
- piece of unlined white paper
- lamp
- watch or clock
- thermometer

Photosynthesis and Light

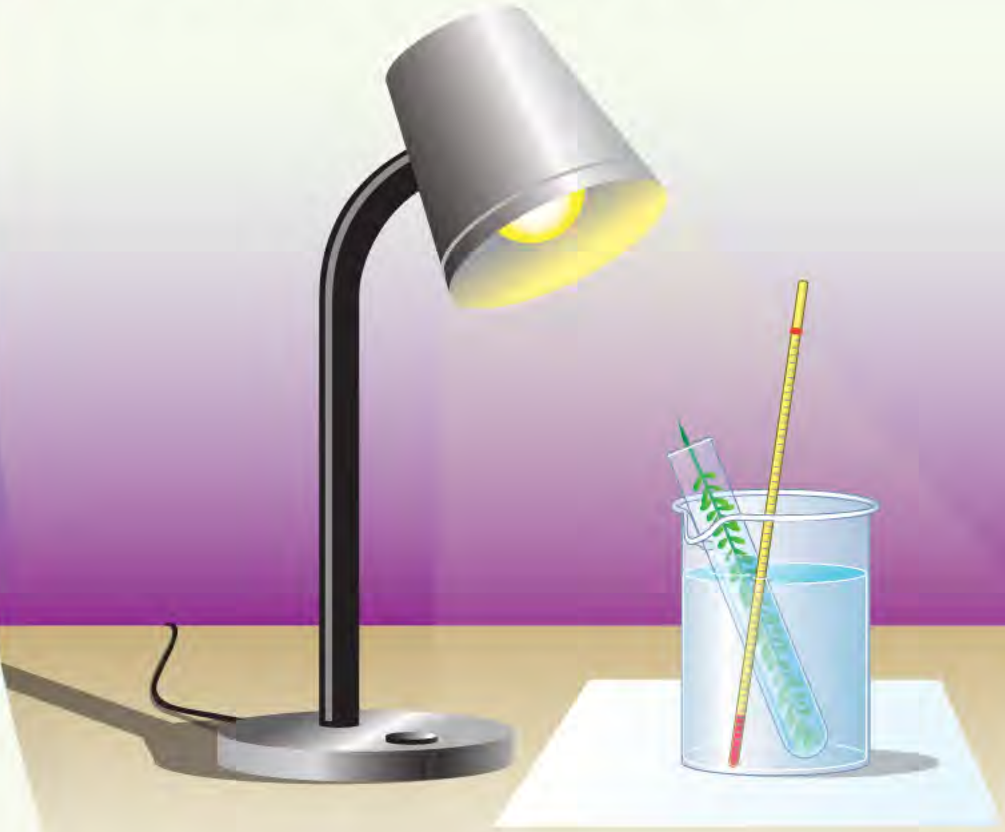
This Investigation is called Guided Inquiry because you are given a question to guide you. You will use this question to help you plan and conduct an experiment to answer the question.

Question

How does the intensity of light affect photosynthesis?

Procedure

1. Cut the bottom end of your plant stem at an angle, and lightly crush the cut end. Place the leaf in a test tube with the cut end at the top. Fill the test tube with water. Stand the test tube and a thermometer in a beaker filled with water.
2. Place the beaker containing your test tube on a sheet of paper under a lamp. Measure and record the temperature of the water in the beaker.



3. When bubbles of oxygen begin to rise from the plant, start to count the number of bubbles per minute. Continue to record data for 10 min.
4. After 10 min, record the temperature of the water in the beaker.
5. Calculate the average number of bubbles produced per minute by your plant.
6. Use your data to form a hypothesis that relates the amount of light to the rate of photosynthesis.
7. Repeat this experiment, but change the light variable so that you are observing your plant's reaction to getting either more or less light. An increase or decrease in water temperature will indicate a change in the amount of light. Keep all other conditions the same.
8. Record your data in a table similar to the one below, and calculate the average number of bubbles per minute.

Number of Bubbles per Minute

Time	Control	Less Light/More Light
1		
2		

Analyze and Interpret

1. How does the amount of light affect photosynthesis? Support your answer with evidence collected during your investigation.

Evaluate

2. Could the rate of photosynthesis be due to temperature? How could you show that temperature is not involved?

Conclude and Communicate

3. Compile all the class data on one graph to show the effects of varying amounts of light on the rate of photosynthesis.

TOPIC
1.4

What interactions occur between humans and micro-organisms?

An ecosystem is any place where living things interact with each other and with their environment. Have you ever thought about your mouth as an ecosystem? About 700 species of bacteria live there. They live on the surface of the tongue and the roof of the mouth, and they coat the teeth and gums. (You may have heard your dentist refer to this coating as biofilm.) Some of these bacteria can cause tooth decay and gum disease. Some have been linked to diseases in other parts of the body, including the heart and pancreas. Other kinds of bacteria help to keep your mouth healthy by outcompeting populations of disease-causing bacteria, which keeps their numbers down.

Key Concepts

- A micro-organism is an organism that can only be seen with a microscope.
- Humans have both negative and positive interactions with micro-organisms.

Curricular Competencies

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest.
- Experience and interpret the local environment.
- Seek patterns and connections in data from your own investigations and secondary sources.
- Exercise a healthy, informed skepticism and use scientific knowledge and findings for your own investigations to evaluate claims in secondary sources.
- Transfer and apply learning to new situations.

Starting Points

Choose one, some, or all of the following to start your exploration of this topic.

1. **Identifying Preconceptions** Microscopic organisms are a part of daily life in many ways. Some of these ways are helpful, and some are harmful. Brainstorm as many examples as you can of helpful and harmful microscopic organisms in your life.
2. **Questioning** Your mouth is not the only part of your body that is home to bacteria and other microscopic organisms. Where else do you think bacteria live in and on your body? How do you know, or what makes you think so?
3. **Applying** The photo below shows a microscopic animal called a tardigrade. It is found in places as diverse as hot springs, deep ocean trenches, and beds of moss. (One of its common names is moss piglet.) Does it surprise you to read that animals can be microscopic? Why or why not? Do you find yourself questioning or rethinking ideas about living things that you have had up to now? Why or why not?

Key Terms

Three key terms are highlighted in bold type in this Topic:

- micro-organisms
- microbes
- pathogens

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

A micro-organism is an organism that can only be seen with a microscope.

Activity

Reflecting on Micro-organisms

Each of the living things in Figure 1.15 is a micro-organism. Record at least five observations and five questions that occur to you as you compare these photos.

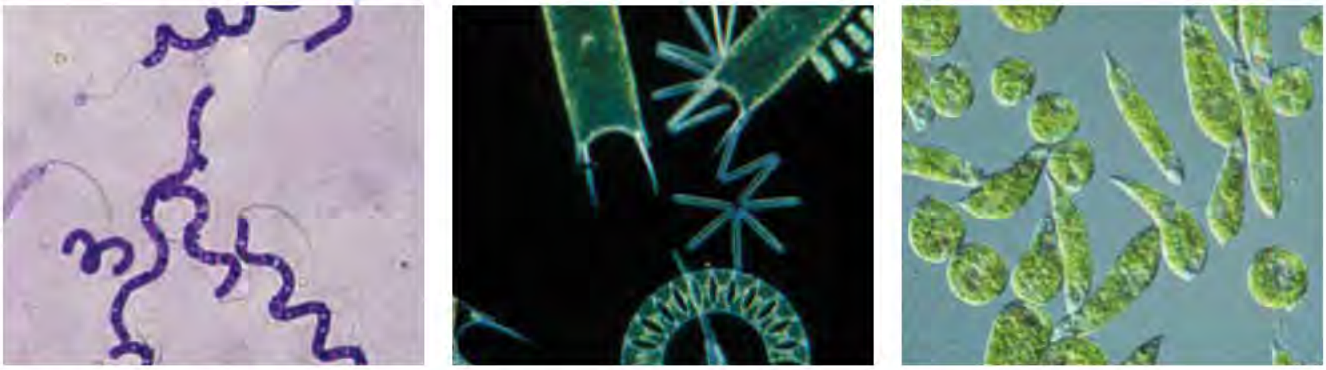
micro-organisms any organisms small enough to need a microscope to be seen

microbes common-language short form for micro-organisms

One thing that the organisms in Figure 1.15 have in common is that they are too small to see with the unaided eye. Anything that is smaller than 1 mm requires technology such as a microscope to see clearly. **Micro-organisms** are all smaller than 1 mm, so they can only be seen with a microscope. For example, each bacterium in Figure 1.15 has a length of about 1 µm. This means that thousands of them could fit in an area the size of the period at the end of this sentence. The phytoplankton are even smaller, with a length of only 0.1 µm. The *Euglena* is a bit larger, with a length of about 10 µm.

Micro-organisms, or **microbes** for short, live in every place you can possibly imagine. They live inside and on other living things. Many live freely in the air, in large and small bodies of water, and even in small puddles. No matter where you travel in the world—along sandy beaches, in coastal and inland forests, into the mountains, across prairie grasslands, in the freezing Arctic, and in dry, hot deserts—there are microbes.

Figure 1.15 These single-celled organisms are found in various ecosystems, some on land and some in the water.



Spirillum volutans; Bacteria;
LM Magnification: 1000x

Various Species of Phytoplankton;
Magnification: Unknown

Euglena gracilis; Protist;
LM Magnification: 200x

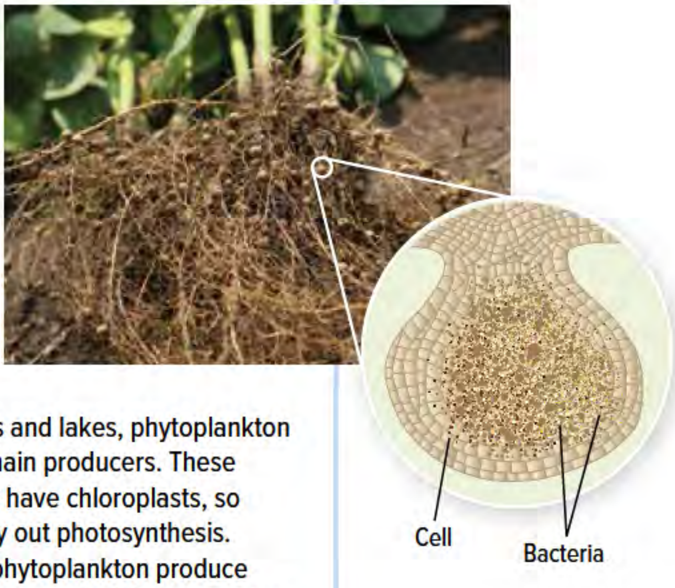
The Importance of Microbes

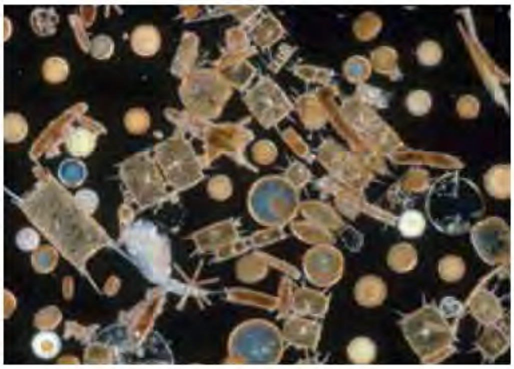
Microbes have important roles in ecosystems. Figure 1.16 shows how bacteria and phytoplankton are important to other living things in an ecosystem.

Many types of bacteria are decomposers. They break down (decompose) dead or waste materials such as rotting wood, dead animals, and animal wastes. The action of decomposers returns nutrients to the soil. Plants and other organisms use these nutrients to grow and carry out their life processes.

Figure 1.16 Forests and other environments could not function without the action of decomposer microbes.

For example, nitrogen is a nutrient that plants and other organisms need. Nitrogen gas makes up about 78 percent of the atmosphere, but it is in a form that plants cannot use. Certain kinds of bacteria make nitrogen available to plants. The bacteria live and grow on the roots of plants such as peas, beans, and alfalfa. As part of their own life processes, the bacteria change nitrogen into a form that the plants are able to use. This usable nitrogen is transferred to other organisms when they eat the plants.





In oceans and lakes, phytoplankton are the main producers. These microbes have chloroplasts, so they carry out photosynthesis. As well, phytoplankton produce about 50 percent of the oxygen in the atmosphere.

Before you leave this page . . .

1. Explain why a microscope is needed to see micro-organisms.
2. You read about roles that bacteria and phytoplankton play in ecosystems. Suggest two other roles that you think microbes play in ecosystems.

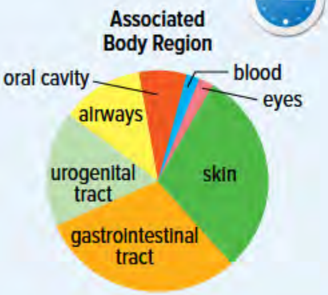
CONCEPT 2

Humans have both negative and positive interactions with microbes.

Activity

Microbes on the Move

The pie chart shows results of an experiment in which microbe samples were collected from surfaces in the New York City subway system. The pie chart shows the sources of the microbes collected. What questions do you have about these data? What would be your next step in the process of scientific inquiry?



Negative Interactions with Microbes

Under favourable conditions, phytoplankton can reproduce very quickly. They form huge, colourful masses called red tides. The red-tide microbes produce toxins that make shellfish such as clams poisonous. First Peoples know to observe the behaviour of coastal animals during red tides. Animals avoiding clams is a sign that they are unsafe to eat. Elders along the coast observe that red tide is becoming more common now than in the past (Figure 1.17).

Red-tide microbes are examples of **pathogens**—microbes that can make people sick. You may have heard of bacteria such as *E. Coli*, *Listeria*, and *Botulism*. These pathogens can cause food poisoning, which can lead to vomiting, diarrhea, and fever.

pathogens micro-organisms that can cause disease

Causing sickness is not our only negative interaction with microbes. For example, bacteria and other microbes such as mould cause food to spoil. Mould can also cause wood to rot, which can affect the structural stability of homes and other buildings that are made with wood.

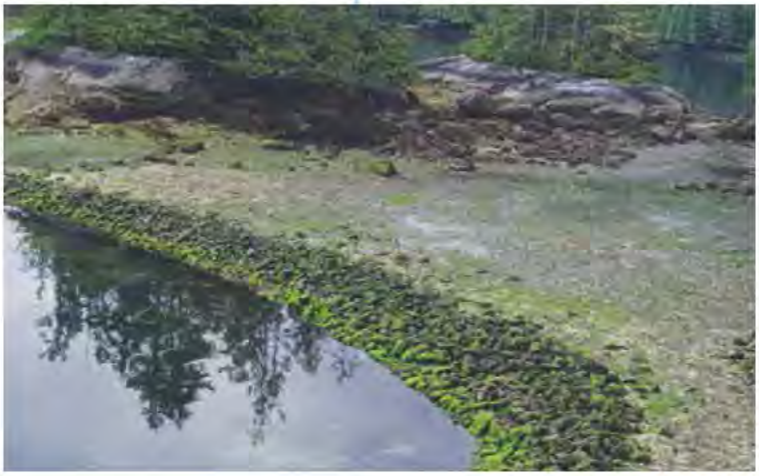


Figure 1.17 First Peoples along the Pacific coast have created clam gardens for millenia. These beach-extending structures are a sustainable source of food and have served as places for Elders to share knowledge and teach skills to the young.

Positive Interactions with Microbes

There are more than 400 types of bacteria in your intestine right now, but they are not making you sick. These bacteria help keep you healthy and are a natural part of your digestive system. Some help you digest food, and some help prevent infection. Certain bacteria in your large intestine help you absorb the nutrient vitamin K, which helps your blood clot properly. Table 1.3 lists more examples of the positive interactions humans have with microbes.

Table 1.3 Some Positive Interactions With Microbes

Interaction	Examples	
Food production	Bacteria are used to make foods such as cheese, yogurt, pickles, soy sauce, and chocolate.	
Medicine production	Bacteria are used to make antibiotics and the insulin that people with diabetes need.	
Agricultural production	Bacteria are used to genetically modify crops so that they are better protected against insects or disease. Scientists also continue to study the importance of bacteria in soil and for the health of crops.	
Waste management	More than 300 species of bacteria are used in water treatment plants to decompose wastes.	
Disaster recovery	Bacteria can be used to help clean up oil spills and areas contaminated by chemical spills or radioactive waste.	

Before you leave this page . . .

1. Make a T-chart to list the positive and negative interactions between humans and microbes.
2. Some medicines people take to treat an infection also kill bacteria that are naturally found in the intestines. Why is this a concern?

SCIENCE AT WORK

Biology Connections

What kinds of jobs are there for people who investigate cells and life processes?

- Artificial Life Programmer
- Environmental Technologist
- Immunologist
- Science Writer
- Virologist

Microbiologist

The next treatments for a damaging disease with antibiotic resistance could be lurking in caves. Want to explore? Microbiologists think big while investigating the very small.

Limnologist

Fresh water makes up 10% of British Columbia's total area, but most people consider it precious beyond compare. Limnologists help keep it that way by studying microbes and other factors that could harm it.

Food Science Technician

Some people protect food from microbes, but food science technicians rely on microbes for the products that form the basis of many delicious and nutritious meals.

Questions

1. What other jobs and careers do you know or can you think of that involve the study of cells, living things, or micro-organisms?
2. Research a job or career related to Unit 1 that interests you. What attracts you to it? What kinds of things do you have to know, do, and understand for this job or career?

Check Your Understanding of **Topic 1.4**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Are bacteria a type of microbe? Why? PA

2. Name two places where microbes can live. PA

3. Describe three characteristics that microbes share with other living things. PA AI

4. A student says that microbes include bacteria and viruses. Another student argues that viruses should not be called microbes. Which student do you agree with? Provide one or two statements that support your position. PA C

5. Bacteria can consume some chemicals that would make humans very ill. This makes them very useful for waste management and disaster recovery. Describe the role bacteria play in addressing these two issues. PA C

6. Create a rap, rhyme, or song that could be used to teach younger students about positive and negative interactions that humans have with microbes. Include at least three positive and three negative interactions. PA AI C

7. The statements below are related to handling food safely. Explain the reason behind each statement. PA AI

- **a)** Frozen meat should be thawed in the refrigerator, not on a counter at room temperature.
- **b)** Cutting boards and dishcloths need to be disinfected after each use.
- **c)** People should wash their hands before and after handling and preparing food.

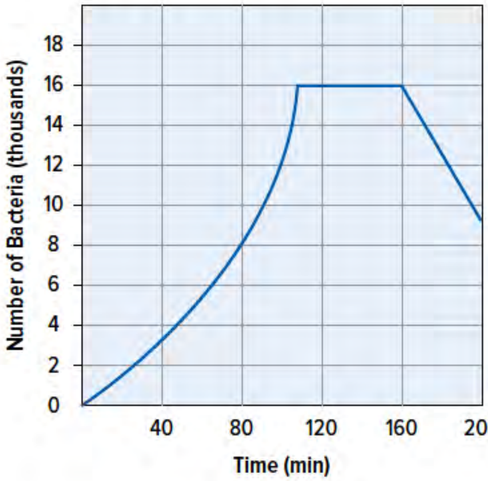
Connecting Ideas

8. Scientists estimate that about 2000 blue whales journey along the British Columbia coast each year. Blue whales are the largest living things on Earth. However, they are unlikely to survive without some of the smallest living things on the planet: microbes. Provide two reasons why this is the case. PA AI E C

Making New Connections

9. The graph shows how a population of bacteria increased in a bowl of broth over a period of time. QP PA AI C

- **a)** Interpret what is happening to the population between 0 and 100 min; and between 100 and 160 min.
- **b)** Infer what is happening to the population after 160 min, and give your reasoning.
- **c)** Assume the temperature of the broth was 60°C. Predict what the graph would look like if the temperature of the broth were 4°C. Explain your prediction.



TOPIC 1.5

How does the body protect us from pathogens?

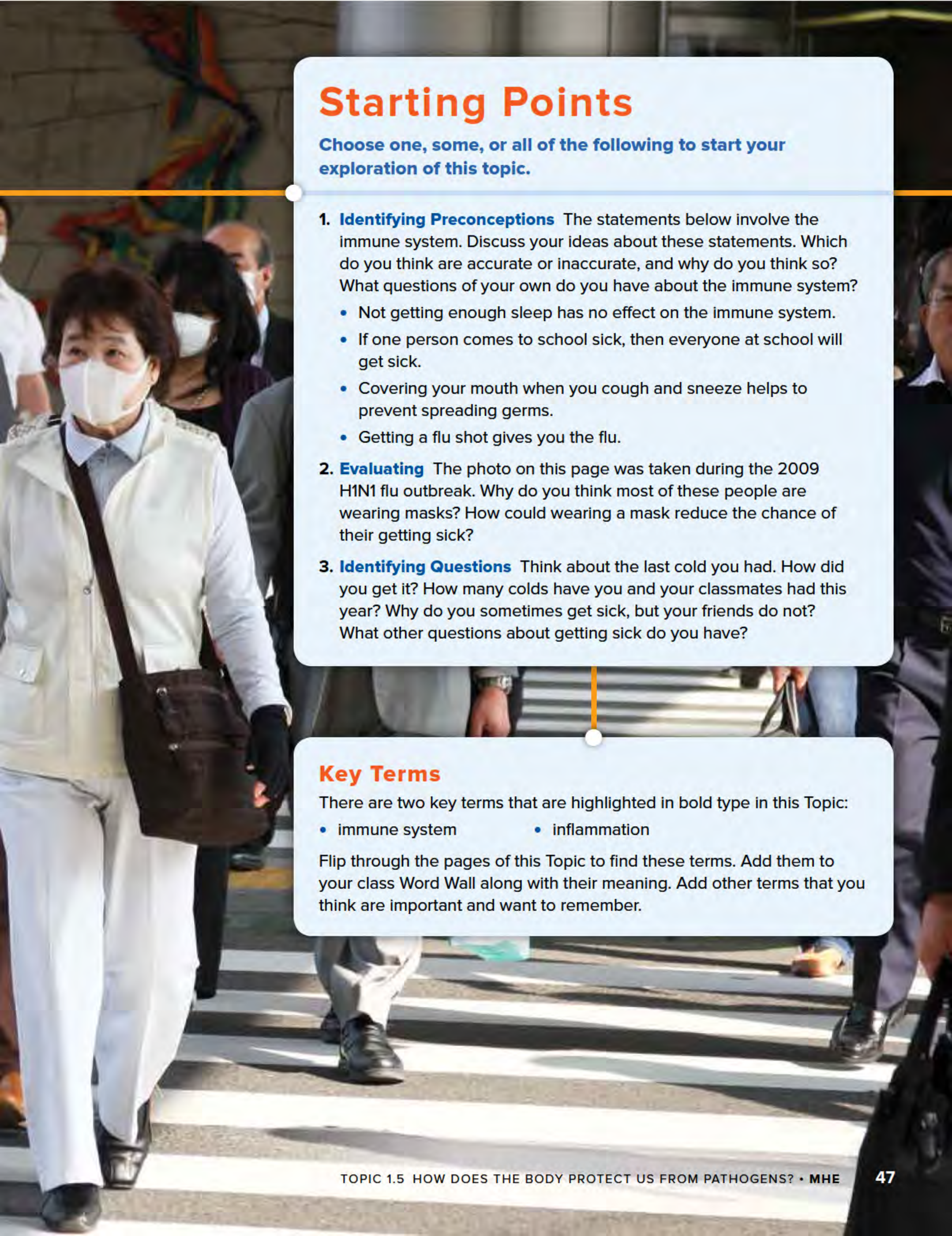
Key Concepts

- The immune system helps protect us from pathogens and infection.
- Outbreaks of disease can have an impact on populations.

Curricular Competencies

- Identify a question to answer or a problem to solve through scientific inquiry.
- Collaboratively plan a range of investigation types to answer questions you have identified.
- Consider social, ethical, and environmental implications of the findings from your own and others' investigations.
- Contribute to care for self, others, community, and world through personal or collaborative approaches.

The influenza virus, which causes the flu, is always changing. That's why many people get flu shots (vaccines) each year. The form of the flu virus that spreads one year is not the same as the forms that people have had shots for in earlier years. Sometimes changes to the flu virus are much more substantial than what researchers normally observe. For example, a virus that infected only birds or pigs may change enough to infect people. That's what happened in 2009 when a new form of influenza virus called H1N1 appeared for the first time in people. It spread quickly in North America, Europe, and Asia. Millions of people became sick, and tens of thousands died. Researchers in several countries worked together to make a vaccine, and programs were set up for people to get it by fall of 2009. By April 2010, the virus was under control. In Canada there were about 45 000 cases and 505 deaths.



Starting Points

Choose one, some, or all of the following to start your exploration of this topic.

1. **Identifying Preconceptions** The statements below involve the immune system. Discuss your ideas about these statements. Which do you think are accurate or inaccurate, and why do you think so? What questions of your own do you have about the immune system?
   - Not getting enough sleep has no effect on the immune system.
   - If one person comes to school sick, then everyone at school will get sick.
   - Covering your mouth when you cough and sneeze helps to prevent spreading germs.
   - Getting a flu shot gives you the flu.
2. **Evaluating** The photo on this page was taken during the 2009 H1N1 flu outbreak. Why do you think most of these people are wearing masks? How could wearing a mask reduce the chance of their getting sick?
3. **Identifying Questions** Think about the last cold you had. How did you get it? How many colds have you and your classmates had this year? Why do you sometimes get sick, but your friends do not? What other questions about getting sick do you have?

Key Terms

There are two key terms that are highlighted in bold type in this Topic:

- immune system
- inflammation

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

The immune system helps protect us from pathogens and infection.

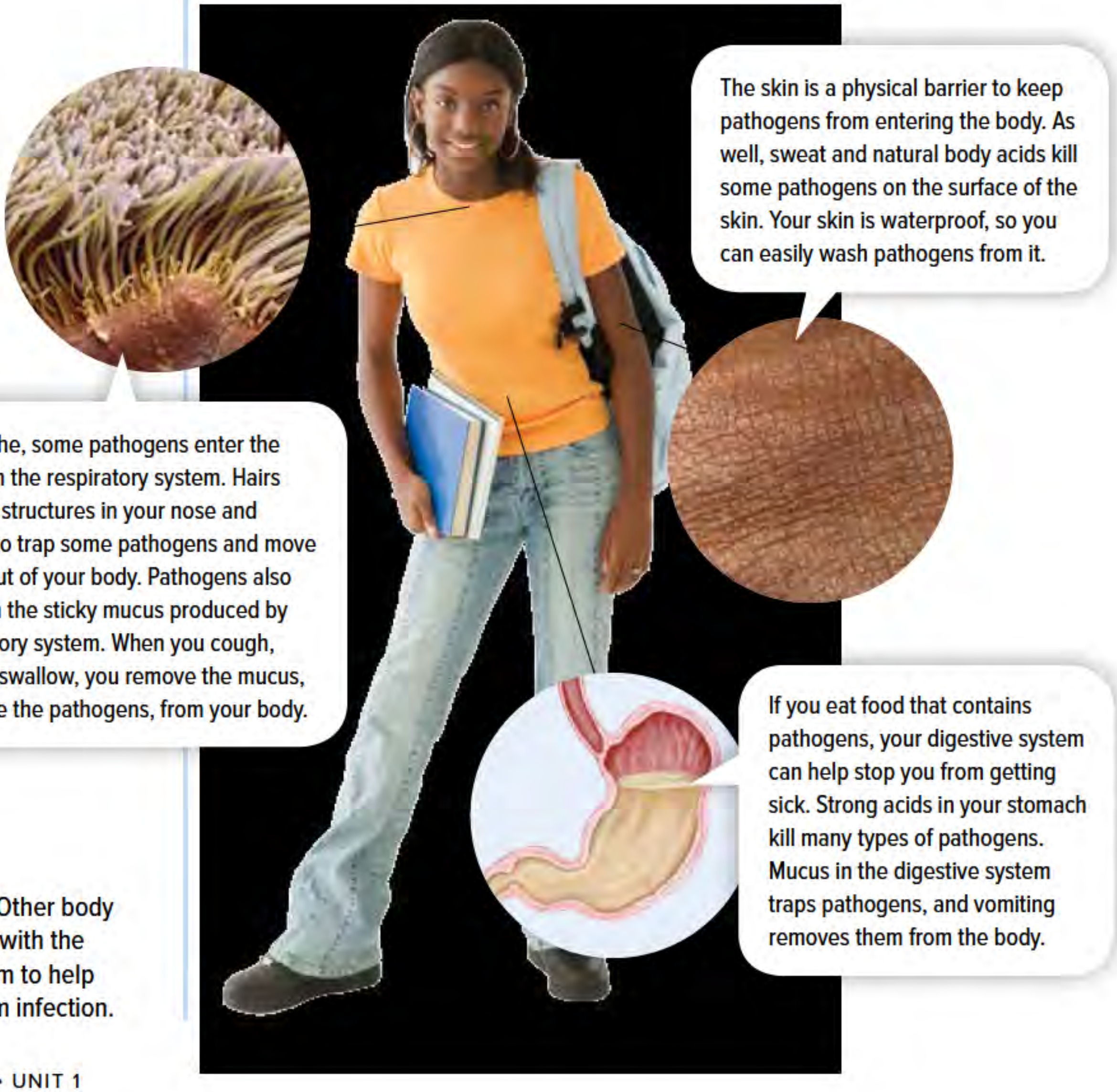
Activity

Introducing the Immune System

Most microbes are harmless to us and many are helpful. However, some cause disease, and we are constantly exposed to them. Why, then, are we not always sick? How does the body protect us? Share and discuss your ideas.

immune system the body system that defends against pathogens and infection

The **immune system** has several lines of defence that help protect us from pathogens. The first line of defence is the skin and the linings of internal body systems. Figure 1.18 shows how different body systems work together to fight against pathogens.



The skin is a physical barrier to keep pathogens from entering the body. As well, sweat and natural body acids kill some pathogens on the surface of the skin. Your skin is waterproof, so you can easily wash pathogens from it.

As you breathe, some pathogens enter the body through the respiratory system. Hairs and hair-like structures in your nose and throat work to trap some pathogens and move them back out of your body. Pathogens also get caught in the sticky mucus produced by your respiratory system. When you cough, sneeze, and swallow, you remove the mucus, and therefore the pathogens, from your body.

If you eat food that contains pathogens, your digestive system can help stop you from getting sick. Strong acids in your stomach kill many types of pathogens. Mucus in the digestive system traps pathogens, and vomiting removes them from the body.

Figure 1.18 Other body systems work with the immune system to help protect us from infection.

The Second and Third Lines of Defence

The immune system has ways to attack pathogens that get by the first line of defence. White blood cells can surround and kill them (Figure 1.19). Some white blood cells release chemicals that make it easier for other white blood cells to kill pathogens.

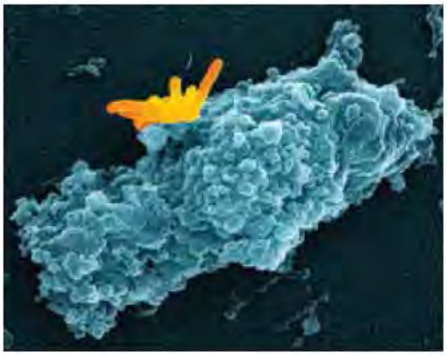


Figure 1.19 A white blood cell (coloured blue) engulfs bacteria (coloured yellow) that have made it past the first line of defence.

If you have an injury or infection, your body responds by getting inflamed. **Inflammation** causes the affected area to become red and swollen like the cut finger in Figure 1.20. White blood cells move to the area, killing pathogens and keeping infection from spreading.

inflammation a process that causes a part of the body to become red and swollen

A third line of defence uses specialized white blood cells to fight a pathogen. In future, if the same pathogen enters the body, these cells can respond quickly so you don't get sick again.

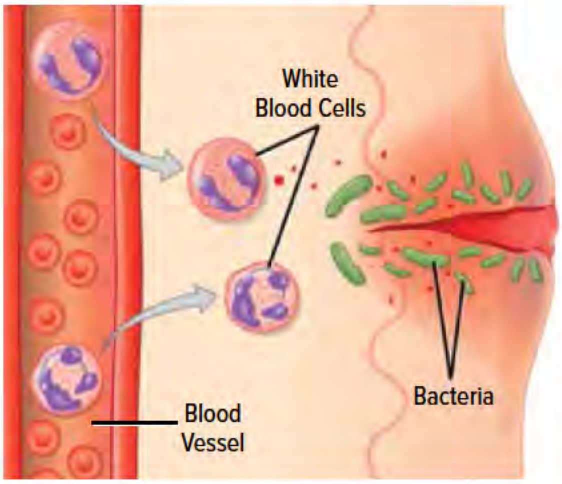


Figure 1.20 When a part of the body is inflamed, it becomes hot and red as blood flow increases. It becomes swollen as fluid floods the tissues. And it becomes painful as nerve endings are stimulated.

Extending the Connections

Exploring the Third Line

Find out about the third line of defence of the immune system. Some keywords to use as a starting point are *antigen*, *antibody*, *B cells*, and *T cells*.

Before you leave this page . . .

1. Trace the path of a pathogen that encounters and gets by the first line of defence but is successfully killed by the second line of defence.
2. How could washing your hands regularly protect you from pathogens?

CONCEPT 2

Outbreaks of disease can have an impact on populations.

Activity

What Do You Do If There's Flu?

The BC Center for Disease Control tracks incidents of influenza and puts out bulletins to communicate its findings. During winter, when flu outbreaks are more common, this information helps inform the public of health threats. If an outbreak were severe, health authorities would share information through the media and your school. Have you experienced changes to your lifestyle or routine due to a flu-related illness? When you hear about an outbreak of flu, what do you think that means? Discuss your ideas with your classmates.

In 2014, the largest and longest outbreak of Ebola virus disease (EVD) to date occurred in West Africa. Symptoms include fever, muscle pain, diarrhea, vomiting, and internal bleeding. EVD is often fatal if left untreated. It is transmitted through direct contact with body fluids of an infected person. Almost 30 000 cases were reported and about 12 000 people died in six countries. Was this considered an outbreak, an epidemic, or a pandemic? Table 1.4 outlines the differences among these three terms, which are used when a disease becomes a concern to society.

Table 1.4 Terms Used to Describe Disease Occurrence

Epidemic	Outbreak	Pandemic
the occurrence of disease cases above the normal amount expected for a population in a defined area	same definition as an epidemic, but often used to refer to a limited geographic area	an epidemic that has spread over several countries or continents, or around the world

Activity

Demonstrate the Difference

Find an example of each term, *epidemic*, *outbreak*, and *pandemic*, from distant or more recent history. Create a presentation to explain how your examples fit the definitions. Share your presentation and compare your examples to those of your classmates. Ask your classmates any questions you have, and be ready to answer their questions.

The Effects of Epidemics and Pandemics on Human Populations

Epidemics and pandemics can have both social and economic impacts on human populations. Figure 1.21 shows some examples.

Figure 1.21 Diseases have social and economic consequences. **Classify each of these four cases as a social impact, an economic impact, or both.**

HIV has killed more than 25 million people since it was first identified in 1984. In just the first two decades of the 21st century, more than 1 million people have died due to diseases such as SARS, H1N1, measles, and typhoid.

Some livestock animals can pass on diseases to people. In 2015, an outbreak of bird flu forced poultry producers to kill about 50 million chickens and turkeys. The price of eggs increased, and farmers lost millions of dollars.

MEDICAL LEAVE
REQUEST
Employee Information
Dates Requested
SARS/SRAS

Sick days take their toll. Flu alone results in losses of half a billion dollars each year to the Canadian economy.

Taking extra precautions, as well as concern about fear and panic, can lead governments to restrict travel as well as the importation of certain foods.

Connect to Investigation 1-D on pages 56–59

Connect to Investigation 1-E on pages 60–63

Different Populations Have Different Immunities

Deadly diseases have struck human populations throughout history all over the world. Examples are plague, smallpox, measles, HIV/AIDS, and SARS. However, no matter where or when a disease outbreak occurs, there are always some people who have a natural resistance to the pathogen and survive.

For example, starting around 300 CE, there were repeated outbreaks of measles and smallpox over hundreds of years in Europe. Many people died in each outbreak. But over time, people's ability to fight the pathogens increased. Populations of people in Europe had built up immunity to these diseases.

Elsewhere, such as North and South America, people had not been exposed to these same pathogens. When Europeans first came here, First Peoples had never been exposed to these pathogens that cause measles and smallpox. Europeans had hundreds of years to build up immunity to these diseases. But people here had no such immunity, and large numbers died.

Figure 1.22 Vampire bats in the Peruvian rain forest carry rabies. The disease can be passed to humans if they are bitten by an infected bat.

Natural Immunity in Human Populations

Scientists are always searching for populations that have natural immunity. For example, rabies is caused by a virus that affects the nervous system. If left untreated, rabies is fatal. In 2012, scientists learned that people in a remote part of the rain forest in Peru had a natural immunity to rabies (**Figure 1.22**). In the small population, about 10 percent had immunity. In Gabon, in west-central Africa, scientists discovered a population with a natural immunity to Ebola. Cases like these help scientists learn more about diseases, how to treat them, and perhaps how to prevent them.

Extending the Connections

Considering Cultural Practices

Each culture has its own ways of caring for people who are dead or dying during an outbreak of a deadly disease. But during the Ebola epidemic in 2014, cultural practices played a role in spreading the disease. How can a public health agency help reduce the spread of disease and still respect local cultures and customs?

Before you leave this page . . .

1. Give examples of a disease with a social impact and an economic impact.
2. Explain how a population can develop immunity to a disease.

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AT ISSUE

How can you evaluate claims about products that boost the immune system?

What's the Issue?

Many products, such as vitamin C or B_6, echinacea, garlic, and ginseng claim to boost or support the immune system. How do you know if the claims these products make are accurate and valid?

For example, some companies make and market garlic pills to boost immunity. These pills come in different dosages, such as 400 mg, 1000 mg, and 2000 mg. Some are mixed with other products, such as parsley or vitamin C or chlorophyll. Do these pills work? Based on laboratory studies, there is evidence that garlic has antibacterial and antiviral properties. However, there are few studies that have been conducted on humans to determine the effectiveness of garlic as an immune system booster.

In one study, a group of people took garlic supplements for three months during cold season. Another group was used as a control. They took a treatment that had no effect on the body. The garlic group got fewer colds. This result appears to support the claim that garlic helps the immune system. But other questions remain unanswered. For example, how do the results of this study and others translate into how much garlic supplements to take, when to take them, and in what form?

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Choose a product that claims to boost or support the immune system.
   a) Investigate the claims made by the maker of the product. Consider the sources you use for your research. Summarize the results of your findings.
   b) If you find the claims to be valid, how does the product boost or support the immune system? What is the best form in which to take the product, what dose, and for how long? What, if any, side effects are there?
   c) If you find the claims to be invalid, what do you think should be done? What would you like to do?
2. What factors influence your opinions about the products you use or want to use? How can you use scientific competencies and knowledge to help you make decisions about the products you choose to buy?

AT ISSUE How Do Travel Restrictions Protect People's Health?

What's the Issue?

Consider this scenario. You are part of a group that has been fundraising and gathering school supplies for students in a developing country. Now your trip to deliver the supplies has been postponed. It may even be cancelled. An epidemic involving a rapidly spreading virus is occurring in the place you plan to visit. The Public Health Agency of Canada has issued a Level 3 Travel Health Notice for your destination. Such a notice is issued when an outbreak affects many people over a large area.

You're disappointed, and you wonder if your trip really does have to be put on hold. You investigate and find that studies of illnesses such as influenza and SARS show that restrictions are not that effective in preventing the spread of these diseases. They may briefly delay the spread to another country. But they do not prevent the disease from crossing international borders. You discuss these results with your teacher sponsor. She argues that, despite your findings, the restrictions still protect the health of the travellers themselves. She challenges you to dig deeper and consider the issue from multiple perspectives.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. The Public Health Agency of Canada issues four levels of alerts when a disease outbreak or epidemic occurs in another country.

- **a)** Create a graphic organizer that compares the four levels of alerts.
- **b)** Identify three ways the alerts help protect travellers.
- **c)** Which alert(s) would make you decide to avoid travel to a restricted country? Explain your decision.

2. SARS stands for Severe Acute Respiratory Syndrome. It can cause serious, life-threatening illness. Early this century, an outbreak of SARS occurred in Canada. As a result, some countries advised that citizens restrict their travel to Canada.

- **a)** Imagine that you lived in another country during the outbreak and were planning a trip to Canada. What other information would you have wanted to know before you decided to cancel your trip?
- **b)** How do you think the foreign travel restrictions may have affected Canada and Canadians?

Check Your Understanding of **Topic 1.5**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. A sneeze is certainly nothing to sneeze at. One sneeze can eject a cloud of microbe-filled, microscopic droplets at speeds of more than 300 km/h.

a) List at least three science-related questions that you have, based on this information.

b) Choose one of your questions, and describe how you would plan an investigation to answer it. QP PC

2. What is the function of the human immune system? PA

3. Identify three examples of the first line of defence of the immune system. Choose one and describe how it works. PA C

4. Explain what inflammation is, which line of defence it is part of, and the role it plays to protect you from microbes. PA C

5. Explain how some people in a population might be immune to a disease. Use an example to help demonstrate your understanding. PA C

6. If you were to build a castle with the best possible defence system, what would you include? Why? How is a castle's defence system like your immune system? PA AI E C

Connecting Ideas

7. There were three flu pandemics during the 20th century. The number of deaths is shown in the table below. (The name of each flu is based on the place where the flu was first reported.)

Years	**Spanish Flu** 1918–1919	**Asian Flu** 1957–1958	**Hong Kong Flu** 1968–1969
Canadian deaths	50 000	2000	3400
Global deaths	20–40 million	2 million	1–4 million

a) Which pandemic was the most deadly?

b) For which pandemics was a flu vaccine likely available? Why do you think so?

c) Why might a flu pandemic eventually stop on its own, instead of eliminating all human life? AI E C

Making New Connections

8. Engineers often design systems so that important parts or functions are duplicated. This is called redundancy. It helps make a system more secure and reliable. If a part or a function fails to work, there is a backup to protect the whole system.

a) In what ways is the immune system a redundant system?

b) Do you find it helpful for your own understanding to compare the biological immune system to a technological system? Give reasons why you do or don't find it helpful. AI E C

INVESTIGATION 1-D

STRUCTURED INQUIRY

Modelling the Spread of Disease

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Applying and Innovating

Safety

- Never eat or drink anything in the laboratory.
- If you spill the contents of your cup, notify your teacher immediately.

What You Need

- paper cup provided by your teacher
- plastic dropper
- “infection indicator” solution (teacher only)

Pathogens can spread from one person to another in several ways, including through the air (when someone sneezes or coughs), through objects, or through insects, such as mosquitoes or ticks. When an outbreak of a disease occurs, public health authorities begin tracking the spread of the disease, trying to find out where it started and who was the first person to get sick. Tracking the origin and spread of an outbreak can help health authorities decide the best way to respond to the outbreak and minimize the number of people infected.

Question

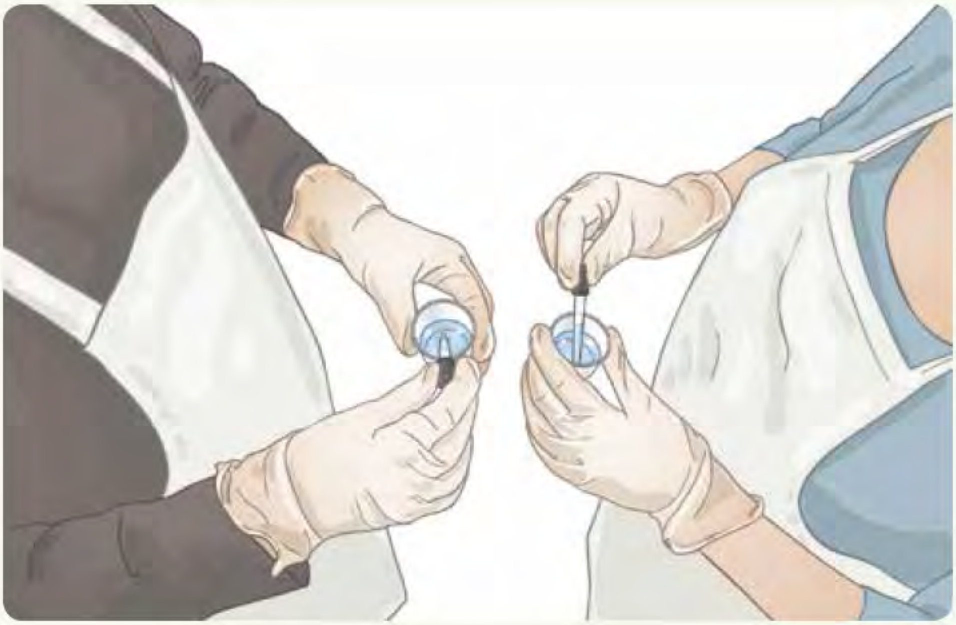
How can you model the spread of disease?

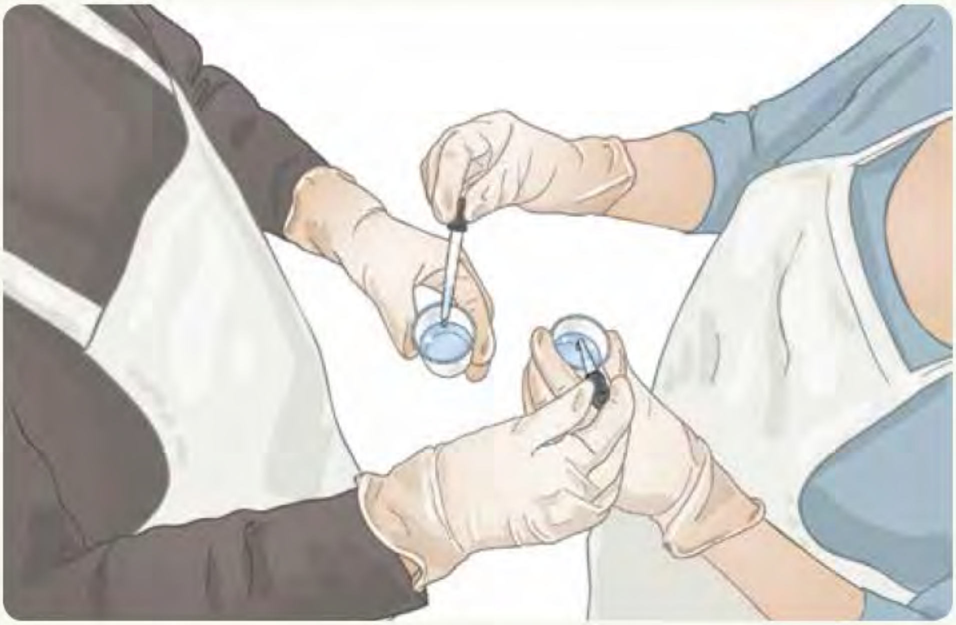
PART A: PROCEDURE

1. Take a paper cup from the cups provided by your teacher. Each cup contains about 10 mL of liquid. One cup contains a fake “pathogen.”
2. When your teacher tells you, walk around the classroom until you are told to stop.
3. Use your dropper to pull some liquid from your cup. Then squeeze three drops into the cup of the person standing nearest to you. Remove the drops from your cup before either of you exchange any drops. After the exchange, place any of your own remaining dropper liquid back into your cup.
4. The dropper of liquid represents a potential passing of the pathogen to another person. Record the name of the person you exchanged drops with in a table like the one below.

My Contact Chart

Your Name	Contact 1	Contact 2	Contact 3





5. Repeat Steps 3 and 4 two more times.
6. Your teacher will put a drop of “infection indicator” in everyone’s cup.
7. If you are “infected,” the liquid in your cup will turn pink.
8. Record whether you are infected or not.
9. Dispose of your cup and liquid according to your teacher’s instructions.

PART B: PROCEDURE

10. Figure out who "patient zero" is. "Patient zero" is a term used by public health agencies to indicate the first person that was infected and passed the pathogen to others.

11. Make a class chart like the one shown below. Fill in the name of each student in the class in the top row. In the columns on the left side, fill in the number of contacts that were made. (A contact was made each time you put drops from your cup into someone else's cup.) In each column below a student's name, fill in the people with whom they made contact.

Patient Zero Tracking Chart

Names of Students in Class							
	Emma	**Mason**	**Logan**	**Harper**	**Benjamin**	**Jun**	**Etc.**
Contact 1	Jun	Chloe	Nabhitha				
Contact 2	I-Wen	Taress	Benjamin				
Contact 3	Joshua	Zoe	Haani				

12. Highlight the names of people in the table who became infected.

13. Track the names of the infected people. Look for people who were infected and all of the people they made contact with and were also infected. These people are possible patient zeroes. In the example above, Mason and Logan can be eliminated as patient zero. Although they each infected their first contact, neither of them infected his second contact.

14. If possible, make a diagram that shows the route of the pathogen being passed from one person to another.

Process and Analyze

1. At first, only one person in the class was infected. By the end of the investigation, how many people in the class were infected?
2. Explain how this investigation models the spread of a disease.
3. Were you able to determine who patient zero was? Why or why not?

Evaluate, Apply, and Communicate

4. How do you think tracking the spread of a disease during an outbreak and determining patient zero help public health authorities stop the spread of disease?
5. Suppose that someone could pass on a pathogen without appearing to be infected. How might that affect the public health authorities' ability to track the spread of the pathogen?
6. Suppose a scientist working in a lab is accidentally and unknowingly exposed to a pathogen. The scientist then leaves work, exposing people to the pathogen and leading to an outbreak. What steps could be taken to avoid a situation like this happening again?

INVESTIGATION

1-E

GUIDED INQUIRY AND OPEN INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

Detecting, Monitoring, and Responding to an Outbreak

In 2004, there was an outbreak of bird flu (avian influenza) on a poultry farm in British Columbia. It is caused by a virus that infects birds, and it also can be transferred to humans. Health authorities at all levels of government responded to the outbreak. They put measures in place to reduce the risk of people being infected. For example, workers who came in contact with farmed poultry were monitored for symptoms of illness and treated if they got sick. So were their families. By the end of the outbreak, only two people had been infected. Both were treated successfully.

A successful outcome to a disease outbreak requires a coordinated effort. Health officials at all levels of government—local, provincial, territorial, and federal—work together to plan how to monitor and respond to an outbreak. They also plan how outbreaks may be detected.

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PART A: DETECTING AND RESPONDING TO AN OUTBREAK—GUIDED INQUIRY

Question

How are outbreaks detected, monitored, and responded to?

Procedure

1. Collaborate to decide how you will plan, conduct, and process the research that you will do. Your goal is to find out and communicate how disease outbreaks in the province are detected, monitored, and responded to.
2. Find answers to the questions below. Also keep a record of any new questions you have as you do your investigation, and research those as well. Then use the questions at the top of the next page to reflect on your findings.

- What is the role of health care professionals during an outbreak of an infectious disease? What agencies may be involved?
- How do local public health authorities monitor and respond to an outbreak?
- What resources can be used to help confirm, monitor, and respond to an outbreak?
- How do factors such as the type of pathogen, how it is transmitted, or the location of the outbreak affect the ways that public health authorities respond to an outbreak?
- What steps do local public health authorities take to control the spread of the pathogen and contain the outbreak?
- At what point may other levels of government get involved?
- What protocols (plans) are in place to notify patients and/or the public about an outbreak?
- How is the public notified of an outbreak? (For example, what news and other media may be used?)
- How is the public informed about best practices to follow to help stop the spread of the disease?
- How are updates provided to the public, and who provides them?
- How do health agencies reflect on what they have learned from an outbreak to better respond to the next outbreak?

3. Decide how you will process, evaluate, and communicate the results of your research. For example, you may find an organizer such as a KWL chart helpful.

Analyze and Interpret

1. Why is it important for health care professionals to report any incidences of notifiable diseases to the proper authorities?
2. Why is it important for public health authorities to monitor an outbreak?
3. What role does the public play in helping to reduce the spread of a pathogen and reduce the size of an outbreak?

Conclude and Communicate

4. Why is communication an important part of monitoring and responding to an outbreak?
5. How do social, economic, or ethical factors influence public health authorities when deciding when and how to notify the public of an outbreak?

PART B: DETECTING AND RESPONDING TO AN OUTBREAK—OPEN INQUIRY

Question

You will determine your own question to investigate. See step 3 of the Procedure.

Procedure

1. Find an example of an outbreak of a disease that has occurred in or near your region.
2. Write out any questions you have about the outbreak. Use the 5 W's (Who, What, Where, When, and Why?) to help you brainstorm questions.
3. Decide which question or questions you will investigate, and plan how you will answer them.
4. Carry out your plan.

Process and Analyze

1. You can show patterns or relationships in your findings using tables, graphs, and digital technologies. Choose the methods that help you organize and examine your findings best.
2. Identify patterns and connections in your findings to make science-based inferences, interpretations, and conclusions.

Evaluate and Communicate

3. Do you think the public health authorities monitored and responded to the outbreak in a satisfactory manner? Give examples and reasons to justify your opinion.
4. What has been and could be done to prevent future outbreaks like the example you chose?

Apply and Innovate

5. Consider the example you chose. Assume that the outbreak has progressed to the point that the public needs to be notified. Create a notification, in a form of your choice, for the public about the outbreak. Include basic information about the disease, the current status of the outbreak, and best practices to follow to help reduce the spread of the pathogen. Consider your audience when creating your notification. For example, "the public" includes people of different ages and backgrounds. How can you tailor your notification to reach the broadest possible audience?

TOPIC 1.6

What medicines help protect us from microbes that make us sick?

Key Concepts

- Traditional First Peoples medicines and treatments come from resources in nature.
- Vaccines can help us prevent infections.
- Antibiotics can treat bacterial infections.

Curricular Competencies

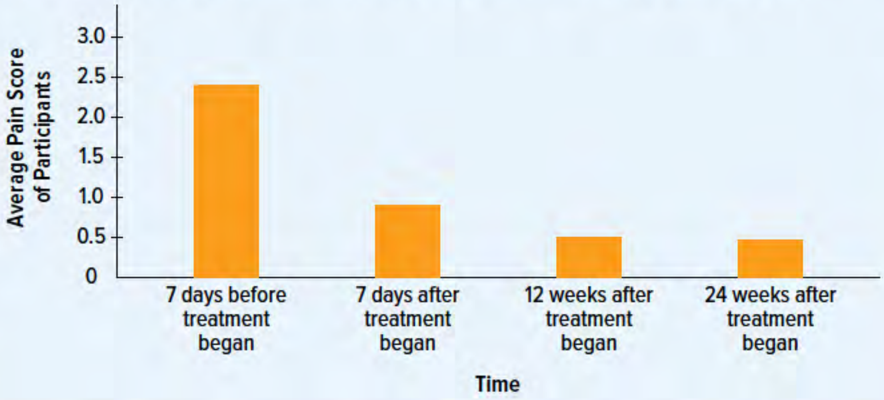
- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest.
- Make observations aimed at identifying your own questions about the natural world.
- Demonstrate an awareness of assumptions and identify information given and bias in your own work and secondary sources.
- Consider social, ethical, and environmental implications of the findings from their own and others' investigations.

There is a new weapon in the fight against dangerous bacteria that resist antibiotics. And that weapon is found here in British Columbia, in a place called Kisameet Bay. Researchers from the University of British Columbia have found that Kisameet clay is able to kill pathogens that have become resistant to modern medicines. This comes as no surprise to the Heilsuk First Nation. They have been using the clay for hundreds of years to treat ulcers, arthritis, burns, and skin disorders. Researchers are investigating the clay to try to understand how and why it is so effective.

Starting Points

Choose one, some, or all of the following to start your exploration of this topic.

1. **Identifying Preconceptions** Which of the following statements do you think are true, and which are false? Why do you think so in each case?
    - Antibiotics are an effective treatment for the common cold.
    - Medicines prescribed by a doctor or developed by reputable pharmaceutical companies are the only reliable way to treat disease.
    - Vaccines do not have a proven track record in the treatment and prevention of disease.
2. **Analyzing** In people with osteoarthritis, the cartilage at the ends of bones wears down over time. Researchers designed a study of the use of ginger to relieve pain caused by this condition. People in the study ranked their pain 7 days before treatment started. Lower numbers represent less pain. Treatment involved a patch of 1 g of ginger mixed with water that was applied to the lower back for 30 min each day. How do you interpret the results shown in the graph?



Key Terms

Two key terms are highlighted in bold type in this Topic:

- vaccine
- antibiotics

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Traditional First Peoples medicines and treatments come from resources in nature.

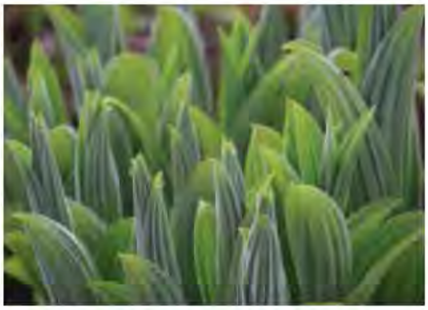
Activity

Ask an Elder or Medicine Person about Medicinal Plants

Which native plants are used as medicines in the place where you live? If possible, invite an Elder or medicine person from a local First Nation to speak to your class about the use of medicinal plants. Your teacher will help you follow the right protocol for when you invite and prepare for a First Nation visitor.

Whether it is using valerian root to help with sleep problems or boiled willow bark to treat an injury, First Peoples in British Columbia have a strong tradition of using resources from nature for medicinal purposes. For generations, First Peoples have relied on plants, animals, and even clay deposits to treat various illnesses and conditions. **Figure 1.23** shows some examples of medicinal plants used by First Peoples of British Columbia.

Figure 1.23 First Peoples have a long history of using plants for medicinal purposes.



Indian hellebore (*Veratrum viride*) can be found in open forests in much of the province. The plant is used by the Nuxalk Nation, for example, to treat skin and scalp conditions. When the plant is burned, the smoke is used as a decongestant.

Devil's club (*Opolopanax horridus*) grows along the coast, as well as in the interior, of British Columbia. Many First Peoples use this plant to treat breathing and digestive disorders, as well as arthritis and diabetes.

Pacific yew (*Taxus brevifolia*) is a small tree found along the coast of British Columbia. Many First Peoples make tea from the needles and bark to treat pain and internal injuries. The tree also has a cancer-fighting chemical in its bark.

Before you leave this page . . .

1. Demonstrate an understanding of how nature can be used to heal.
2. Why might it be important to identify and preserve plants used for medicinal purposes?

AT ISSUE

What factors put medicinal plants at risk?

What's the Issue?

Since time immemorial, First Peoples here and other Indigenous peoples around the world have used plants for healing purposes. Over time, people have discovered ways to prepare and use plants to treat stomachaches, aching joints, sore eyes, fevers, nosebleeds, and coughs and colds. Today, medicinal plants are important on both a global level and local level. More than five billion people rely on plants as their primary source of medicine. For some people, harvesting and selling medicinal plants is their only source of income.

However, some medicinal plants are at risk of being lost. Some may be destroyed as the land on which they grow is claimed for other uses, such as commercial farming or housing. Another reason is that as the medicinal properties of certain plants are studied and commercial interest in them increases, some medicinal plants are in danger of being overharvested. It is estimated that about 15 000 different types of medicinal plants are at risk for extinction due to overharvesting.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. Do you believe that medicinal plants and other traditional medicines can or should be patented? What kinds of protections do you think there should be—not only for the plants, but also for the people who use and depend on them?
2. Suppose there is a proposal to cut down a large tract of forest so the land can be used to grow agricultural crops. The forest is a source of medicinal plants that are important to people in the region. You are going to a town hall meeting where this issue will be discussed and voted on. Prepare a list of questions to help you decide how you might vote.
3. What medicinal plants grow in your area? How are they used? Are any of the plants at risk? What factors are putting them at risk, and what can be done to change the situation?

CONCEPT 2

Vaccines can help us prevent infections.

Activity

What Do You Know About Vaccines?

Many babies get vaccines to protect them against diseases such as tetanus, whooping cough, measles, hepatitis B, and chicken pox. What do you know about vaccines? What questions do you have about vaccines? Discuss your ideas with your classmates.

vaccine a substance that causes a response in the body that protects it against a specific disease

A **vaccine** is a substance that is given to a person or animal to protect against a specific disease. Vaccines may be injected or taken orally. They are usually given to babies and children according to a schedule based on age.

Vaccines cause an immune response from the body, which results in the immune system "remembering" the exposure to the pathogen. If a person is exposed to that same pathogen after being vaccinated, the immune system recognizes it and immediately begins to defend the body against it. A vaccinated person does not get sick from exposure to the pathogen and is said to have immunity against the disease. Table 1.5 describes several types of vaccines.

Table 1.5 Types of Vaccines

Type of Vaccine	How It Works	Example
Live, attenuated vaccine	The vaccine contains living microbes that have been weakened in a laboratory so that they cannot cause disease. The immune system responds as if the body has been infected, providing strong, often lifelong, immunity against the disease after only one or two doses.	Used against microbes that cause measles, mumps, chickenpox, and yellow fever are made this way.
Inactivated vaccines	The vaccine contains microbes that have been killed with heat, chemicals, or radiation. This vaccine results in a weaker response from the immune system. To keep immunity, a person has to get booster shots periodically.	Used against hepatitis A, rabies, and whooping cough.
Subunit vaccines	Only specific pieces of microbes are used to make the vaccine. These pieces are separated from the microbe or made in a laboratory. Immunity is provided after several doses.	Vaccines include those for hepatitis B and a flu vaccine called Hib.
Toxoid vaccines	The vaccine is made using toxins that some types of bacteria produce. The toxins are inactivated in a laboratory so they no longer cause disease. Booster shots are usually needed to keep immunity strong.	Vaccines include those for diphtheria and tetanus.

Vaccines and Public Health

Many health agencies in Canada and around the world make strong arguments in favour of people getting vaccines. There are several reasons. For example, vaccines help protect each person who receives them against deadly diseases and diseases that can cause permanent damage, such as blindness, muscle paralysis, heart damage, and infertility. Vaccines can also help stop the spread of disease. The more people who receive vaccines against an infectious disease, the less the disease can spread from person to person.

Connect to Investigation 1-G on page 78

Connect to Investigation 1-H on page 79

Vaccines can also help stop an outbreak from turning into an epidemic or pandemic. For example, throughout history, smallpox has been a devastating disease. However, after a worldwide vaccination effort in the 20th century, the disease was declared eradicated in 1980. The last known natural case of smallpox occurred in Somalia in 1977. Many organizations are working to eradicate other diseases, including polio and measles. **Table 1.6** shows examples of vaccines that have been effective at preventing diseases.

Table 1.6 Effectiveness of Certain Vaccines

Disease	Number of Reported Cases, 1980	Number of Reported Cases, 2014	Percent Decrease in Cases
Diphtheria	97 774	7321	92.5
Measles	4 211 431	267 582	93.6
Polio	57 795	371	99.4
Tetanus	114 248	11 392	90.0
Whooping cough	1 982 384	220 504	88.9

Before you leave this page . . .

1. In your own words, explain what a vaccine is.
2. Make a graphic organizer of your choice to explain how vaccines help protect people against disease.

CONCEPT 3

Antibiotics can treat bacterial infections.

Activity

What Do You Know About Antibiotics?

Have you ever taken an antibiotic? Can you explain how it helped you? If not, how could you find the answer to this question? What other questions do you have about antibiotics?

antibiotic a substance that fights infections by interfering with the life processes of bacteria

Antibiotics are substances that fight infections by interfering with the life processes of bacteria. Either they kill bacteria or they prevent them from growing or reproducing. Each antibiotic is effective against specific types of bacteria. They are not useful against infections caused by viruses or other microbes.

Penicillin—The First Antibiotic Available on a Global Scale

Connect to Investigation 1-F on pages 76–77

As it sometimes happens in science, the discovery of penicillin was an accident. In 1928, a British scientist named Alexander Fleming returned to his laboratory from holiday to find several Petri dishes with *Staphylococcus* bacteria growing on them. One dish also had a large patch of mould growing on it. What caught Fleming's eye was that no bacteria were growing around the mould. The Petri dish Fleming found is shown in Figure 1.24. The mould had properties that stopped the bacteria from growing near it.

The scientific name of this mould is *Penicillium notatum*. Penicillin is the antibiotic that was derived from this mould. It was used to treat soldiers for bacterial infections during World War II. By 1950, it was widely available to the public, and the development of other antibiotics soon followed. You may have heard some of their names, such as erythromycin, amoxicillin, and tetracycline.

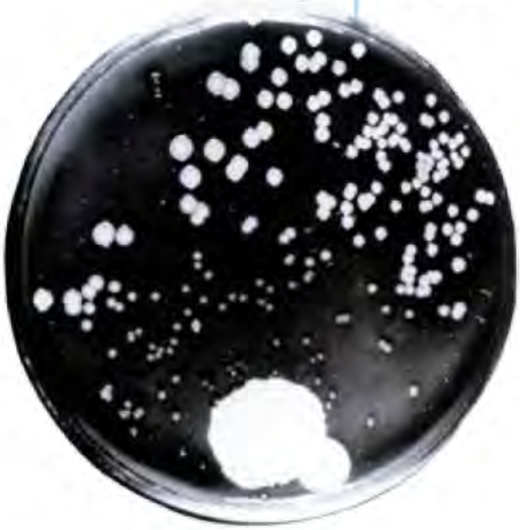
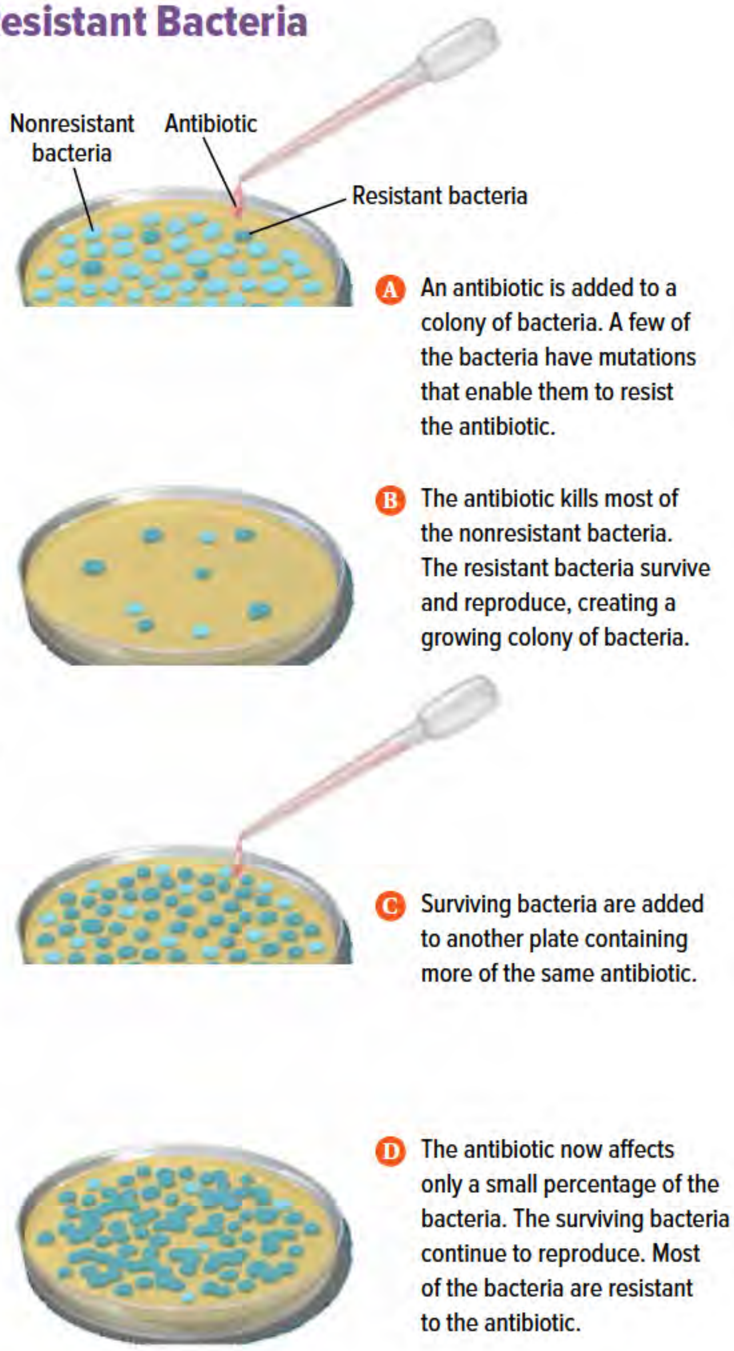


Figure 1.24 The area near the mould does not have bacteria growing around it. What questions would you have asked if you had seen this Petri dish? Describe a controlled experiment that you would have carried out to answer these questions.

The Development of Antibiotic-Resistant Bacteria

Millions of people have benefited from the use of antibiotics since their discovery. However, a serious problem has arisen from their overuse. Many types of bacteria have become resistant to antibiotics. Some diseases, such as tuberculosis, pneumonia, and meningitis, are now more difficult to treat as a result of antibiotic-resistant bacteria. Figure 1.25 explains how a population of bacteria can become resistant to bacteria.

As time passes, the resistant bacteria will reproduce and become more common. As a result, the antibiotic is no longer effective against those bacteria. When this happens, a different antibiotic must be used to fight the infection. In recent years the term "superbugs" has been used to describe bacteria that are resistant to several types of antibiotics. One of the more common superbugs is methicillin-resistant *Staphylococcus aureus* (MRSA). Scientists are continuing to research new ways to treat infections caused by antibiotic-resistant bacteria.



A An antibiotic is added to a colony of bacteria. A few of the bacteria have mutations that enable them to resist the antibiotic.

B The antibiotic kills most of the nonresistant bacteria. The resistant bacteria survive and reproduce, creating a growing colony of bacteria.

C Surviving bacteria are added to another plate containing more of the same antibiotic.

D The antibiotic now affects only a small percentage of the bacteria. The surviving bacteria continue to reproduce. Most of the bacteria are resistant to the antibiotic.

Figure 1.25 A population of bacteria can develop resistance to bacteria after being exposed to them over time.

Before you leave this page . . .

1. What are antibiotics? How are they used?
2. Suppose you had to describe to a grade 3 class how antibiotic-resistant bacteria develop. Create a brief presentation in the format of your choice to meet this goal.
3. Why do you think the medical community is concerned about antibiotic-resistant bacteria?

TAKE Action

Make a Difference

Implement a Handwashing Campaign

How often do you touch your face during the day? If you're like most people, you touch your nose, mouth, eyes, or ears many times, probably without even being aware of it. How clean are your hands throughout the day? Where have they been before you touch your face? What do you touch afterwards?

You cannot avoid coming in contact with microbes. They are everywhere in the world around you, indoors as well as outdoors. However, it is the pathogens that can cause disease that are a concern because they are so easily picked up, dropped off, and moved from object to object and from place to place.

Where do they come from and how do they get there? Consider each time you

- touch a doorknob
- tap a touchscreen
- shake someone's hand
- handle raw food
- use toilet paper
- cough
- sneeze

What other examples can you think of? Do you regularly wash your hands before or after you do any of these things?

Handwashing Helps

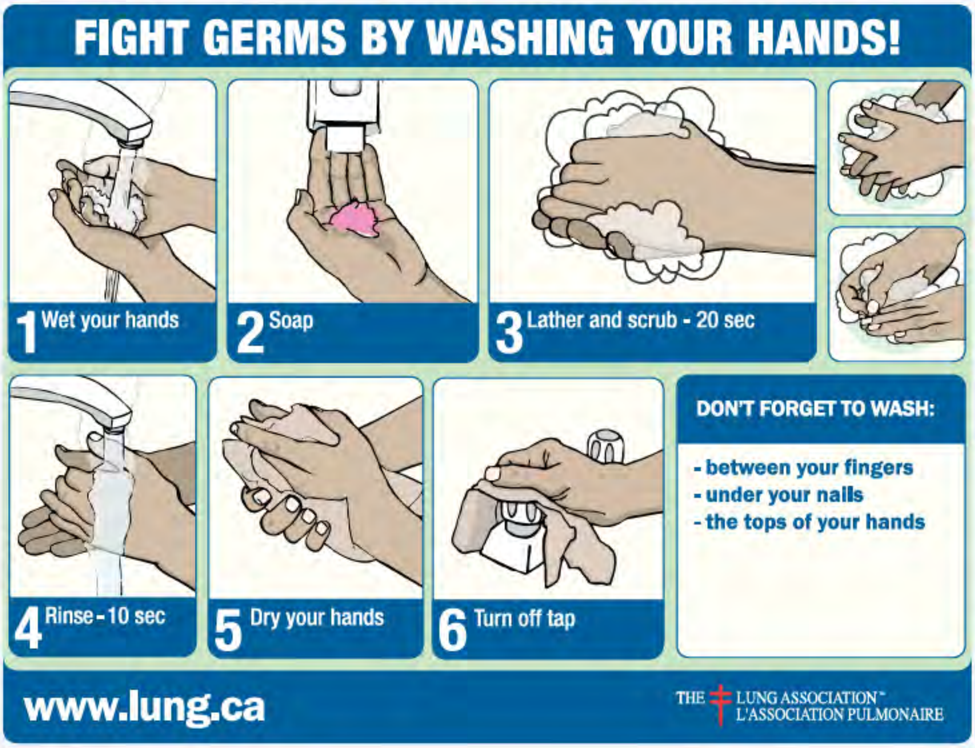
Washing hands with soap kills and removes pathogens and is a proven way to reduce their spread. Communities where people have been shown the importance of handwashing have seen a 31% decrease in the number of people who get sick with diarrhea. They've seen up to a 20% decrease in the number of people who get sick from colds and other respiratory infections.

According to the Canadian Centre for Occupational Health and Safety (CCOHS), handwashing with soap is the most effective way to reduce the spread of infections. It also helps reduce the development of antibiotic-resistant bacteria. When fewer people get sick, fewer antibiotics are prescribed. This, in turn, decreases the chances of bacteria developing resistance to antibiotics.

There's a Proper Way

Washing your hands may seem like a simple thing to do, but there actually is a "right" way to do it. And scientists estimate that only about 5% of people wash their hands properly. Proper hand washing begins with removing jewellery from hands and arms and then following the steps shown in the poster.

One thing the poster doesn't say is to avoid using antibacterial soap. It can kill the healthy bacteria that live on your skin. And it can contribute to the development of antibiotic-resistant bacteria.


FIGHT GERMS BY WASHING YOUR HANDS!
1 Wet your hands
2 Soap
3 Lather and scrub - 20 sec
4 Rinse - 10 sec
5 Dry your hands
6 Turn off tap
DON'T FORGET TO WASH:
- between your fingers
- under your nails
- the tops of your hands
www.lung.ca
THE LUNG ASSOCIATION
L'ASSOCIATION PULMONAIRE

An easy way to time 20 seconds is to remember that it is about the amount of time it takes to sing or hum the "Happy Birthday" song twice.

Questioning and Planning for Your Own Handwashing Campaign

Your task is to run a handwashing campaign in a setting of your choice. Research more information about successful campaigns. Some questions you could consider include, but are not limited to, the following.

- Where will you run your campaign—at home? at school? somewhere else in your community?
- Who will be your target audience?
- What information do you need to investigate and learn about?
- What catchy title can you create?
- Many successful campaigns have slogans, posters, videos, and information on websites. How will you get your message across?
- How can you evaluate the success of your campaign?

Analyze and Evaluate

1. How successful was your campaign? How well did your evaluation plans help you determine its success?
2. What have you learned that could help you improve the campaign?

Apply and Innovate

3. Take your campaign to the next level. For example, if you conducted it at home, consider running it at your school. If you ran it at school, consider a different school or somewhere else in your community. What changes do you need to make for a larger place and audience?

TAKE a Stand

Make a Difference

What can be done to prevent superbug outbreaks?

You volunteer at a long-term care home for seniors in your community. In your orientation package, a brochure discusses a superbug called MRSA. MRSA stands for methicillin-resistant *Staphylococcus aureus*. (Methicillin is a very powerful antibiotic.) Many people carry MRSA but do not get sick from it. However, when MRSA is transferred to people with weak immune systems, it can cause a deadly infection. As a result, MRSA is most dangerous in hospitals and care homes where people live close together. These places follow procedures to prevent infections and keep them from spreading.

The procedures include mandatory handwashing, extensive disinfecting, and screening new residents for MRSA. But not all long-term care homes follow them. Sometimes the home is underfunded and understaffed. You wonder how you could increase awareness of this issue. You decide to do some research.

Some things you learn include the following:

- 1 in 4 people in long-term care homes carry the bacteria that cause MRSA. If they go to a hospital, they bring the bacteria with them.
- Preventing infections takes time and money. Many long-term care homes do not have enough money or staff.
- All long-term care homes in the province must be open for inspection by health authorities. However, even a home with a High Risk rating is inspected just twice a year. A long-term care home with a Low Risk rating is only inspected every 18 months.

Analyze

1. What are the pros and cons of following the prevention procedures?
2. Should governments provide more funding for long-term care homes? Where could the money come from?
3. How might the long time between inspections affect infection prevention?

Communicate

4. Do you think this health problem and the factors that contribute to it can be improved? If not, what obstacles to improvement are there? If so, what do you think can, or must, be done? In either case, what additional information would you want or need to help you reach an informed opinion on the matter?

Check Your Understanding of **Topic 1.6**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Use a Venn Diagram to compare and contrast antibiotics and vaccinations. PA C

2. Describe the role an accident played in the development of the first antibiotic. PA C

3. Name a viral disease that people can be vaccinated against.

4. Explain why vaccination has helped to drastically reduce the number of reported cases of diseases such as measles in Canada. PA C

5. The active ingredient in aspirin is salicylic acid. It was first isolated from the bark of the willow tree. Today salicylic acid is made in laboratories by drug companies. Describe at least one benefit and one drawback of making salicylic acid this way. PA E AI

6. You are creating a health file about vaccines for HealthLink BC. PA AI E C
   - **a)** What information do you think is most important to include in the file? Explain your reasoning.
   - **b)** Create a graphic organizer to include in the file. It should clearly explain the four different types of vaccines that you learned about in this topic.

7. Develop a script that could be used for a 20-second PSA (public service announcement) about superbugs. PA AI E C

Connecting Ideas

8. It is recommended that pregnant women, infants, and people with weak immune systems should not be vaccinated for certain diseases. Explain how it is still possible for vaccines to protect these people from the diseases. (Hint: Think carefully about how the words "vaccinated" and "vaccines" are used in this question.) PA AI E

9. Many microbes and viruses that cause disease can be on our hands. In the last few years, use of alcohol-based hand sanitizers has become common. Why should you limit the use of hand sanitizers to your hands and not use them on the rest of your body? E AI C

Making New Connections

10. Methicillin-resistant *Staphylococcus aureus* (MRSA) is a common superbug. It has caused illness in many places throughout Canada, including British Columbia. QP PC AI
    - **a)** Imagine that you are a scientist who has developed a new antibiotic for MRSA. Describe how you could plan an investigation to test how effective the antibiotic is.
    - **b)** Imagine that you are a doctor working with patients who have MRSA. The antibiotic that was developed in part a) turns out to be effective. List three questions you would have about the antibiotic before you would believe that it is safe to use it for your patients.

INVESTIGATION
1-F

STRUCTURED INQUIRY

Antibacterial Agents (Dry Lab)

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

Safety

CAUTION: This procedure has been modified so that you can measure, record, and analyze results without working with live bacteria.

What You Need

- ruler

You will learn and analyze a technique used to test how effective antibacterial agents are in limiting bacterial growth. An antibacterial agent is a substance that kills bacteria or inhibits (stops or slows) their ability to reproduce. Soap, mouthwash, and antibiotics are examples.

Question

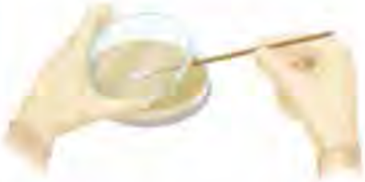
How effective are different antibacterial agents?

Procedure

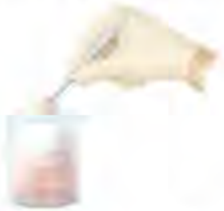
1. Read the boxed information about testing antibacterial agents.
2. Read the tests described in Part 1 and Part 2.
3. Perform the procedural steps in Part 2 and answer the questions that follow.
4. Answer the questions that follow both parts.

Testing the Effectiveness of Antibacterial Agents

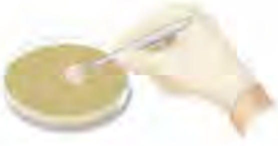
Scientists use these steps to test the effectiveness of different antibacterial agents.



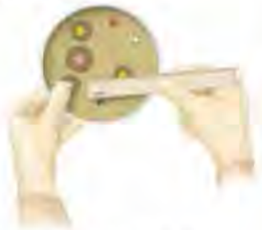
A The entire surface of a plate of nutrient medium is swabbed with the organism to be tested.



B A sterile paper disc is dipped into the antibacterial agent, or antibiotic is applied to the disc.



C The disc with the antibacterial agent is placed in the centre of the agar plate.



D After 18 h of incubation, the zones of inhibition at 37°C (diameters of the clear areas around the discs) are measured in millimetres.

Determining Effectiveness

If an antibacterial agent is effective at killing bacteria, then there will be a circular area around the paper disc that does not have any bacteria. This area is called a zone of inhibition. It is related to the effectiveness of the agent. The larger the zone, the more effective an agent is. Zones of inhibition can be compared by sight (qualitative), or they can be measured with a ruler (quantitative).

Part 1: Testing Antibiotics

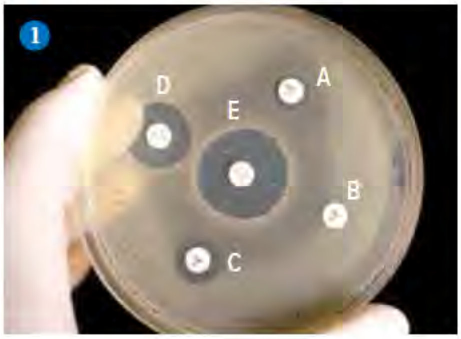
Four antibiotics were tested to determine how well they inhibit the growth of bacteria. The photo shows five discs on a bacteria-covered plate. Four of the discs had an antibiotic applied to them. A fifth disc had water applied to it as a control.

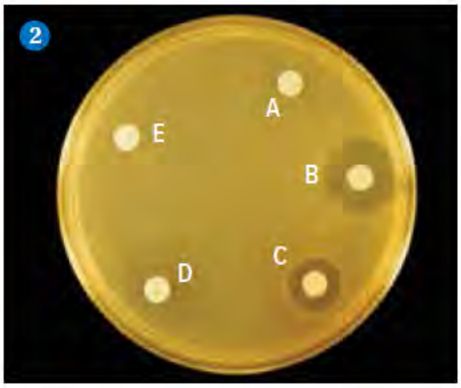
Part 2: Testing Antiseptics

Antiseptics, such as mouthwash and ointments, have antibacterial properties that are gentle enough to be used on skin. Five antiseptics were tested for how well they inhibit the growth of bacteria. The photo shows five discs on a bacteria-covered plate. The antiseptics used were

- (A) Brand L mouthwash
- (B) an antibacterial solution used in hospitals to prepare patients for surgery
- (C) the main ingredient in an over-the-counter antibacterial cream
- (D) iodine
- (E) Brand S mouthwash

1. Use a ruler to measure the zone of inhibition for each disc. To do this, measure the diameter of the circle surrounding each disc.
2. Organize your results in a table.





Analyze and Interpret

1. Sketch the plate for Part 1.
2. Which disc do you think had the most effective antibiotic? Explain your choice.
3. Which disc do you think was the control? Explain your choice.
4. Sketch the plate for Part 2. Include a legend that shows the treatment each label (A to E) represents.
5. a) Which antiseptics were most effective? Which were least effective? How do you know?
   b) Are these results what you would have expected to see? Explain why or why not.

Conclude and Communicate

6. In Part 1, you assessed results by sight. In Part 2, you took measurements. Which method of observation—qualitative or quantitative—do you think was better for assessing the results of the tests? Why?

Apply and Innovate

7. For safety, this Investigation was done as a "dry lab." Results were provided, and you analyzed them. How could an investigation like this with actual organisms be done safely? In other words, what organism could you grow (and test) safely with as little danger as possible of people getting sick? Discuss your ideas in class. Do not carry them out without your teacher's input and guidance.

INVESTIGATION

1-G

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- graph paper
- coloured pencils
- metric ruler

Measles Incidence and Vaccinations

Year	Incidence of Measles (*indicates estimation)	Percent Vaccinated
1980	4 211 431	13
1983	3 843 120*	36
1986	2 375 248*	60
1989	1 984 329*	73
1992	1 499 898*	80
1995	760 634*	80
1998	694 466	80
2001	846 765	72
2004	509 734	85
2007	280 771	90

Measles Vaccination

Measles is a viral infection that causes high fever and a cough. A vaccine for measles has been available since the early 1960s. The World Health Organization (WHO) tracks data on the incidence of measles as well as the percentage of people around the world who get the measles vaccine each year. Do you think there is a link?

Question

What is the relationship between vaccination and the incidence of measles?

Procedure

1. Construct a graph to plot the data. Place *Year* on the *x*-axis. Place *Incidence of Measles* on the left *y*-axis and *Percent Vaccinated* on the right *y*-axis.
2. Decide how you will represent each part of the data on your graph. For example, you could choose to represent the *Incidence of Measles* data using bars and the *Percent Vaccinated* data using a line.
3. Use coloured pencils to plot the points on your graph.

Analyze and Interpret

1. Describe the connection between the incidence of measles and the percentage of people receiving a vaccine each year.
2. Explain why you think this connection exists.

Conclude and Communicate

3. In British Columbia, it is recommended that infants and young children receive a measles vaccine. In several other provinces, measles vaccines are required for school entrance. However, exemptions are possible for medical or religious reasons, or reasons of conscience. Write a short paragraph expressing your opinion about exemptions. Consider how exemptions might affect public health.

INVESTIGATION

1-H

OPEN INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

What You Need

- access to print, digital, and human resources
- supporting materials provided by your teacher to help you organize and plan your thinking and research

Approaches to Health and Wellness

People in different fields of inquiry and understanding draw on a variety of ways of approaching health and wellness. For example:

- Scientists testing Kisameet clay have found that it can kill the seven pathogens that are most resistant to antibiotics
- Medical engineers design nanoparticles that can deliver medicine to specific parts of the body; other researchers are working on new vaccines against various diseases.
- Elders, medicine people, and others who are wise in other ways of knowing, teach about attitudes, practices, and remedies that have supported health and wellness for thousands of years.

What assumptions and understandings do these and other approaches to health and wellness share? Where do they disagree? How much, or little, do they have in common? There are many questions one could investigate about health and wellness.

Question

What question about treating and preventing illness or maintaining health and wellness do you want to investigate?

Procedure

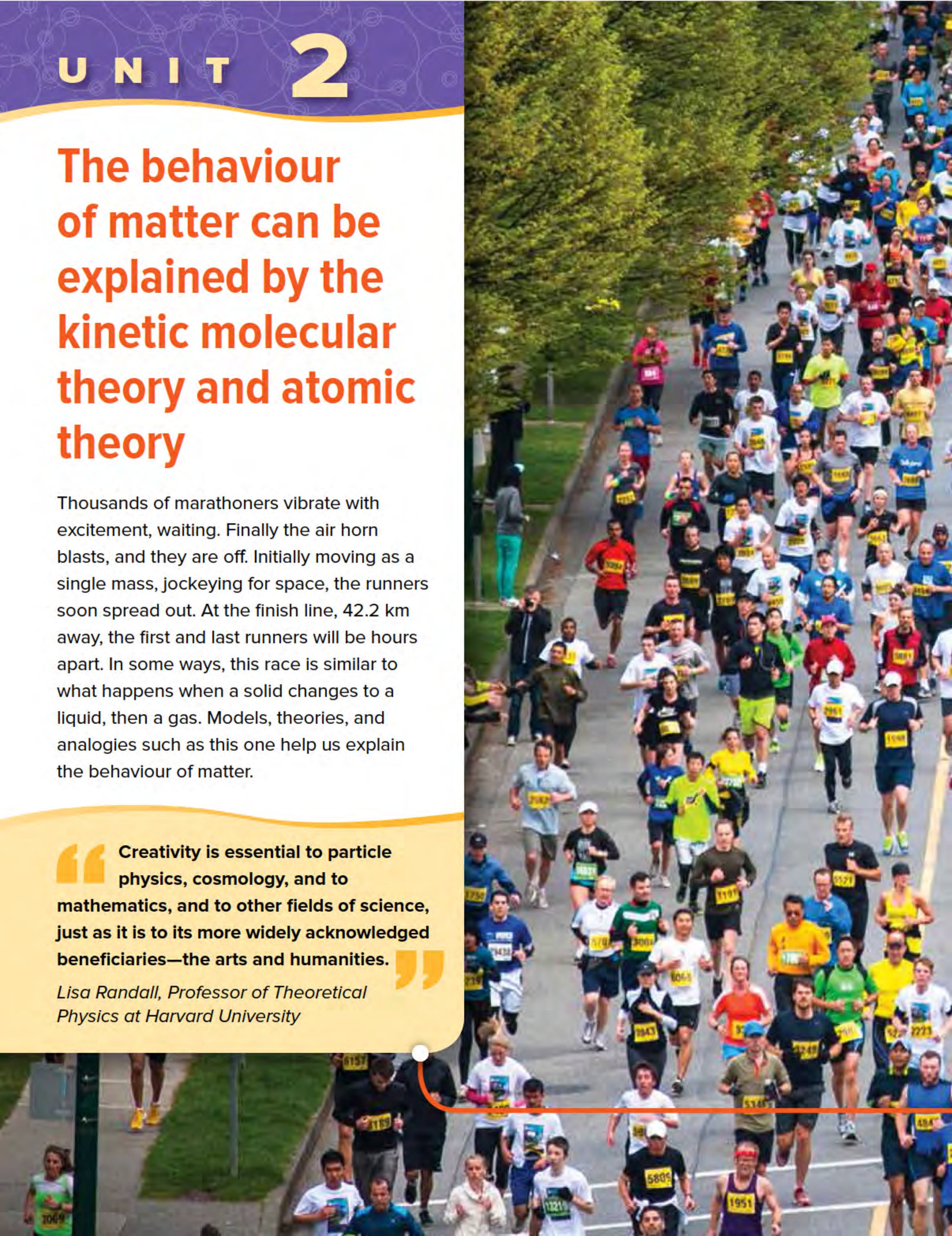
1. Reflect on ideas you have about health and wellness.
2. Write questions you have about the ideas you listed.
3. Choose one question, and develop a plan to find answers.

Analyze, Evaluate, and Communicate

1. Should western, biomedical ways of knowing be balanced with First Peoples and other ways of knowing? Why or why not?
2. What can be lost when First Peoples and other ways of knowing are excluded in matters related to health and wellness?

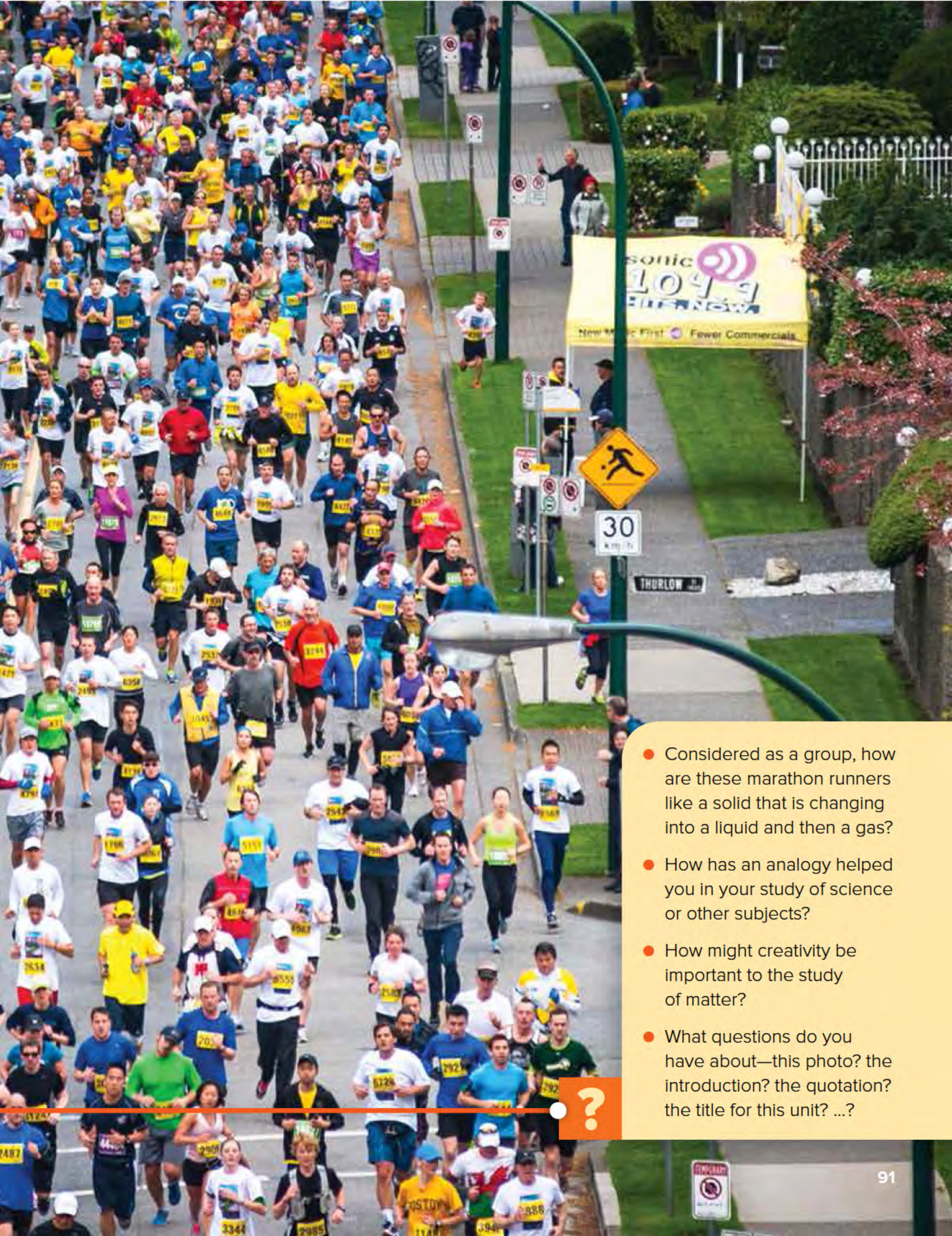
UNIT 2

The behaviour of matter can be explained by the kinetic molecular theory and atomic theory



Thousands of marathoners vibrate with excitement, waiting. Finally the air horn blasts, and they are off. Initially moving as a single mass, jockeying for space, the runners soon spread out. At the finish line, 42.2 km away, the first and last runners will be hours apart. In some ways, this race is similar to what happens when a solid changes to a liquid, then a gas. Models, theories, and analogies such as this one help us explain the behaviour of matter.

> **“Creativity is essential to particle physics, cosmology, and to mathematics, and to other fields of science, just as it is to its more widely acknowledged beneficiaries—the arts and humanities.”**
>
> *Lisa Randall, Professor of Theoretical Physics at Harvard University*


sonic 104.9
HITS NOW
New Music First Fewer Commercials
30 km/h
THURLOW

- Considered as a group, how are these marathon runners like a solid that is changing into a liquid and then a gas?
- How has an analogy helped you in your study of science or other subjects?
- How might creativity be important to the study of matter?
- What questions do you have about—this photo? the introduction? the quotation? the title for this unit? ...?

UNIT 2

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations to explore the behaviour of matter as it undergoes physical and chemical changes
- Develop and use models and other methods to represent the composition and behaviour of matter at the particle/atomic level
- Seek patterns and connections to describe the relationships between the behaviour of matter in our surroundings and its composition
- Use scientific understandings to describe and evaluate the development of atomic theories

ESSENTIAL QUESTION

How do the kinetic molecular theory and atomic theory help us explain the behaviour of matter?

TOPIC 2.1:
How does matter affect your life?

Some things you will do:

- ensure that safety and ethical guidelines are followed in your investigations
- contribute to care for self, others, community, and world through personal or collaborative approaches
- connect scientific explorations to careers

Some things you will come to know:

- the chemical nature of the world around you
- characteristics of chemicals that make them useful, hazardous, or both
- ways to handle chemicals and equipment safely

TOPIC 2.2:
What are some ways to describe matter?

Some things you will do:

- observe, measure, and record qualitative and quantitative data with accuracy and precision
- use scientific understandings to identify relationships and draw conclusions
- reflect on your investigation methods and the quality of the data collected
- communicate ideas, findings, and solutions to problems using scientific language, representations, and technologies

Some things you will come to know:

- how to observe and describe physical and chemical properties of matter
- how to observe and describe physical and chemical changes of matter
- methods for measuring and determining various properties of matter
- the significance of the law of conservation of mass

TOPIC 2.3:
How can we describe and explain the states of matter?

Some things you will do:

- make observations aimed at identifying your own questions about the natural world
- construct and use a range of methods to represent patterns or relationships in data
- generate and introduce new or refined ideas when problem solving

Some things you will come to know:

- properties of the states of matter
- how thinking about matter as being made of moving particles can help to explain the properties and changes of states of matter
- how the kinetic molecular theory extends to other physical properties and changes

A BOY
AND
HIS
ATOM

TOPIC 2.4:
How can we investigate and explain the composition of atoms?

Some things you will do:

- collaboratively plan a range of investigation types
- seek patterns and connections in data from your own investigations and secondary sources
- demonstrate an understanding and appreciation of evidence
- transfer and apply learning to new situations

Some things you will come to know:

- how models and thinking about the nature of the atom have changed over the centuries
- the role of collaboration in the development of the atomic theory
- why scientific inquiry and the understandings that result from it are part of an ongoing, self-correcting process

UNIT 2

The behaviour of matter can be explained by the kinetic molecular theory and atomic theory

Thousands of marathoners vibrate with excitement, waiting. Finally the air horn blasts, and they are off. Initially moving as a single mass, jockeying for space, the runners soon spread out. At the finish line, 42.2 km away, the first and last runners will be hours apart. In some ways, this race is similar to what happens when a solid changes to a liquid, then a gas. Models, theories, and analogies such as this one help us explain the behaviour of matter.

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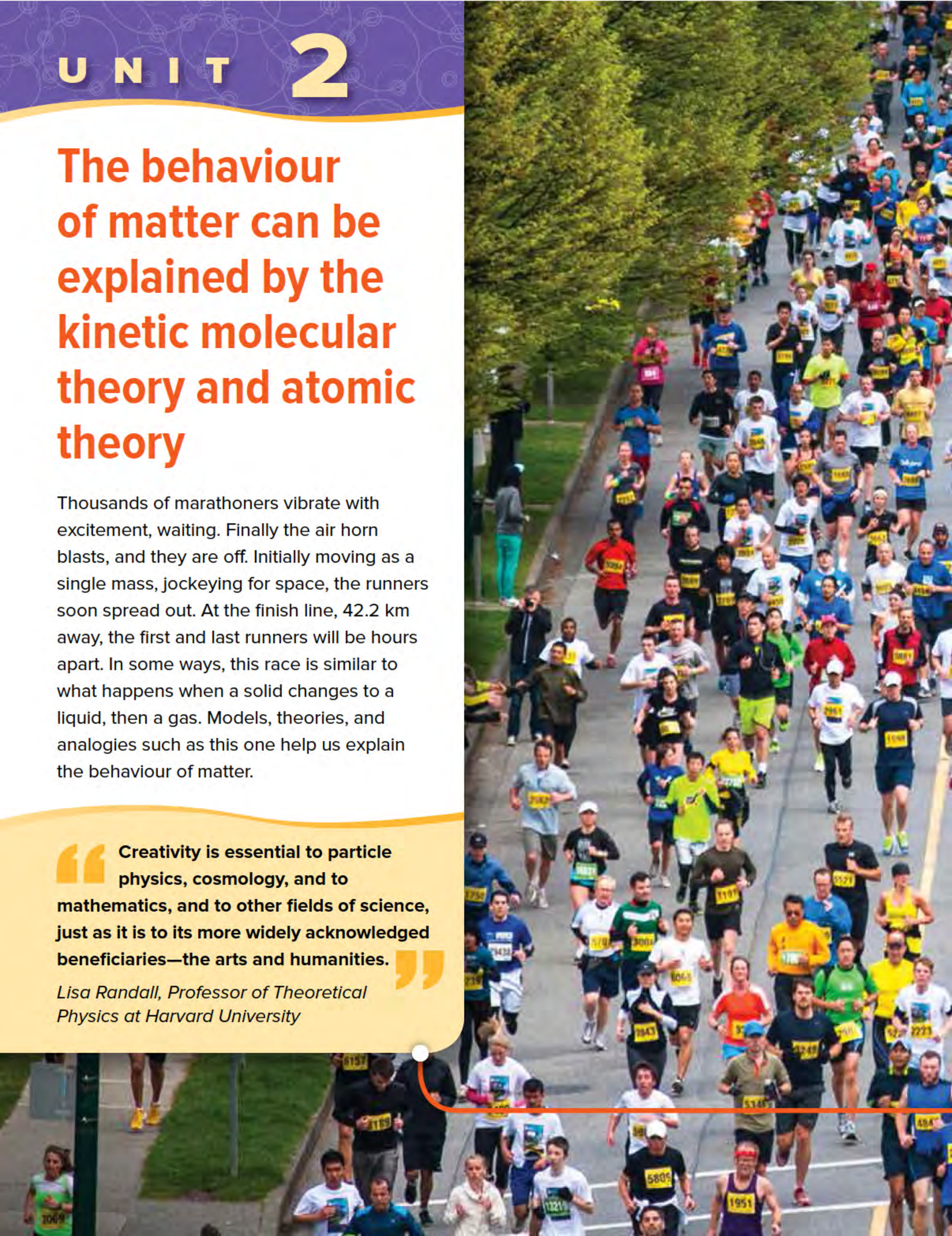
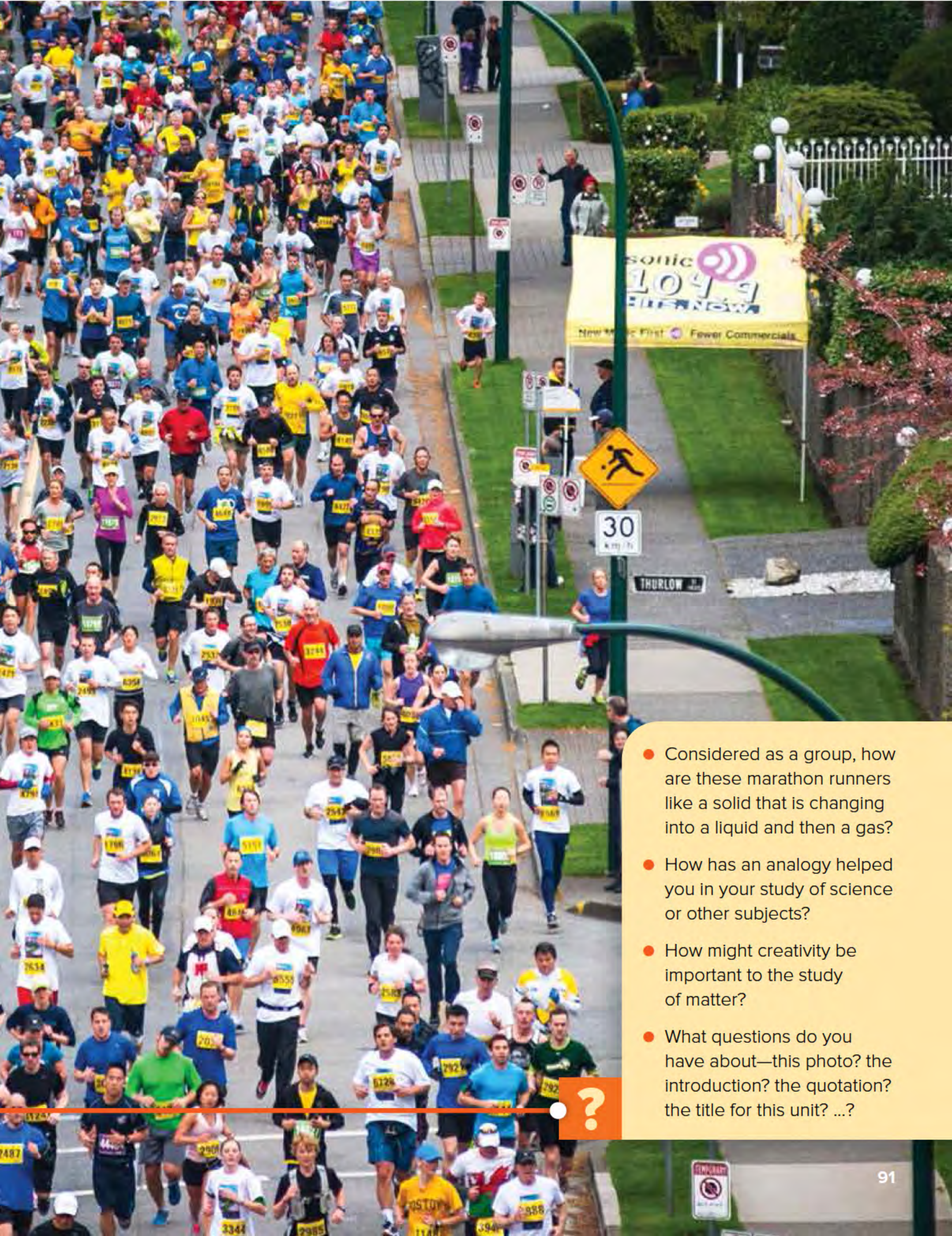



sonic 104.9
HITS NOW
New Music First Fewer Commercials
30
km/h
THURLOW

- Considered as a group, how are these marathon runners like a solid that is changing into a liquid and then a gas?
- How has an analogy helped you in your study of science or other subjects?
- How might creativity be important to the study of matter?
- What questions do you have about—this photo? the introduction? the quotation? the title for this unit? ...?

UNIT 2

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations to explore the behaviour of matter as it undergoes physical and chemical changes
- Develop and use models and other methods to represent the composition and behaviour of matter at the particle/atomic level
- Seek patterns and connections to describe the relationships between the behaviour of matter in our surroundings and its composition
- Use scientific understandings to describe and evaluate the development of atomic theories

ESSENTIAL QUESTION

How do the kinetic molecular theory and atomic theory help us explain the behaviour of matter?

TOPIC 2.1:
How does matter affect your life?

Some things you will do:

- ensure that safety and ethical guidelines are followed in your investigations
- contribute to care for self, others, community, and world through personal or collaborative approaches
- connect scientific explorations to careers

Some things you will come to know:

- the chemical nature of the world around you
- characteristics of chemicals that make them useful, hazardous, or both
- ways to handle chemicals and equipment safely

TOPIC 2.2:

What are some ways to describe matter?

Some things you will do:

- observe, measure, and record qualitative and quantitative data with accuracy and precision
- use scientific understandings to identify relationships and draw conclusions
- reflect on your investigation methods and the quality of the data collected
- communicate ideas, findings, and solutions to problems using scientific language, representations, and technologies

Some things you will come to know:

- how to observe and describe physical and chemical properties of matter
- how to observe and describe physical and chemical changes of matter
- methods for measuring and determining various properties of matter
- the significance of the law of conservation of mass

TOPIC 2.3:

How can we describe and explain the states of matter?

Some things you will do:

- make observations aimed at identifying your own questions about the natural world
- construct and use a range of methods to represent patterns or relationships in data
- generate and introduce new or refined ideas when problem solving

Some things you will come to know:

- properties of the states of matter
- how thinking about matter as being made of moving particles can help to explain the properties and changes of states of matter
- how the kinetic molecular theory extends to other physical properties and changes

A BOY
AND
HIS
ATOM

TOPIC 2.4:

How can we investigate and explain the composition of atoms?

Some things you will do:

- collaboratively plan a range of investigation types
- seek patterns and connections in data from your own investigations and secondary sources
- demonstrate an understanding and appreciation of evidence
- transfer and apply learning to new situations

Some things you will come to know:

- how models and thinking about the nature of the atom have changed over the centuries
- the role of collaboration in the development of the atomic theory
- why scientific inquiry and the understandings that result from it are part of an ongoing, self-correcting process

UNIT 2

Summary

ESSENTIAL QUESTION

How do the kinetic molecular theory and atomic theory help us explain the behaviour of matter?

TOPIC 2.1:
How does matter affect your life?

- Everything—including you—is made up of chemicals.
- Chemicals in your daily life have characteristics that make them useful, hazardous, or both.
- Handling chemicals and equipment safely is important at school and at work.

Key Terms

matter

TOPIC 2.2:
What are some ways to describe matter?

- Matter can be described by its physical properties.
- Matter can be described by its chemical properties.
- Matter can be described based on physical and chemical changes.
- Matter can be classified based on how it responds to physical and chemical changes.

Key Terms

physical property
mass
volume
density
chemical property
physical change
chemical change

TOPIC 2.3:
How can we describe and explain the states of matter?

- Matter can be solid, liquid, or gas.
- Matter is made of particles in constant motion.
- Changes in state result from changes in particle motion.
- The kinetic molecular theory explains physical changes and properties.

Key Terms

model
theory
kinetic molecular theory of matter

A BOY
AND
HIS
ATOM

TOPIC 2.4:
How can we investigate and explain the composition of atoms?

- Dalton developed an early atomic theory.
- Many scientists contributed to the further development of atomic theory.
- An atom is made up of electrons, neutrons, and protons.
- Atomic theory continues to develop.

Key Terms

electrons
nucleus
protons
neutrons
atom

UNIT 2

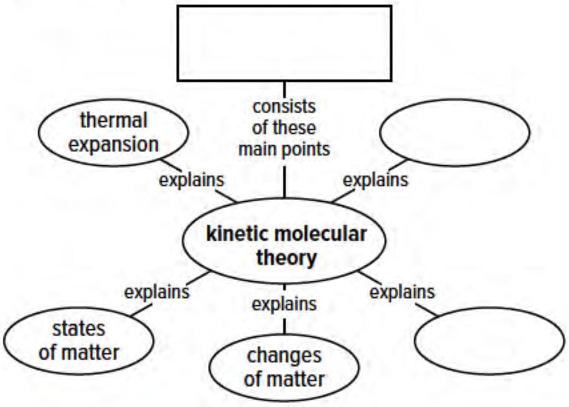
Review

What Do You Know?

Connecting to Concepts

Visualizing Ideas

1. Use this incomplete concept map as a starting point to make your own concept map to show what you know about the kinetic molecular theory.



Using Key Terms

2. For each of the lists of terms below, write a sentence that shows your understanding of the terms and uses all of the terms in the list.
   - **a)** mass, volume, density
   - **b)** model, theory

Communicating Concepts

3. List three safety rules to follow when working in your school laboratory. Explain why each rule is important.

4. Identify each of the following physical properties as qualitative or quantitative.
   - **a)** colour
   - **b)** melting point
   - **c)** density
   - **d)** odour

5. Explain why density is more useful for identifying a substance than either mass or volume alone.

6. Draw simple diagrams to show how the particles are arranged in a solid, liquid, and gas.

7. Use the kinetic molecular theory to explain what happens when a pot of water "boils dry." Include a diagram.

8. Over time, ice cubes left in a freezer appear to shrink.
   - **a)** Which term describes what is actually happening to the ice cubes?
   - **b)** Use the kinetic molecular theory to explain this observation.

9. What are expansion joints and why are they needed? Use the kinetic molecular theory in your explanation.

10. Briefly explain why Thomson's experiments resulted in Dalton's model of the atom being revised.

11. Copy the following table into your notebook and complete it. Allow plenty of space for the sketches.

Model	Key features	Labelled sketch
Dalton's model		
Thomson's model		
Rutherford's model		
Bohr's model		

12. Compare each of the following pairs of particles in terms of their mass, charge, and location in the atom.
   - **a)** proton and electron
   - **b)** proton and neutron

13. Explain the difference between the terms *subatomic particle* and *elementary particle*. Give examples.

What Can You Do?

Connecting to Competencies

Developing Skills

14. Use the following data to answer the question below.

Substance	Density (g/cm³)
water	1.00
cooking oil	0.93
corn syrup	1.36

The mass of an empty container is measured and found to be 55.75 g. The container is filled to the rim with water. Its mass is measured again and found to be 105.75 g. The container is emptied and dried with a paper towel to remove any traces of water. It is then filled with an unknown liquid. The new mass is 123.75 g. Is the unknown liquid cooking oil or corn syrup? Support your answer.

15. For an investigation, you and your lab partner are given a vial of an unknown substance that is a white powder at room temperature. You need to design a procedure to study the physical and chemical properties of the material to help identify it.

- **a)** Decide on what physical and chemical properties would be most useful to use. Explain why you chose those.
- **b)** Write out the procedure. Make sure to include detailed steps to follow to study each property.
- **c)** What safety icons should accompany the procedure? Describe any safety precautions a student should take when performing the tests.

16. The table on the right shows data from an experiment in which a certain amount of liquid was heated.

Time (min)	Temperature (°C)
0	25
2	35
4	45
6	55
8	65
10	75
12	85
14	95
16	99
18	100
20	100
22	100

- **a)** Use the data to plot a graph of temperature versus time.
- **b)** Identify the temperature at which a change of state has occurred, and name that change of state.
- **c)** Describe the particles of the liquid before the liquid was heated, while the liquid was being heated at 10 min, and after the change of state occurred.
- **d)** Make sketches to illustrate your descriptions in part c).
- **e)** Use the kinetic molecular theory to explain what is happening in this situation.
- **f)** Can you use the atomic theory to explain what is happening in this situation? Give reasons why or why not.
- **g)** At the start of this question, you read that a “certain amount” of liquid was heated. Does it matter if you don’t know the precise amount? Use scientific understanding to support your opinion.
- **h)** Make an inference about what the liquid was. Support your inference with evidence from the data.

17. In reality, the oxygen atoms that you can see in the image from the film "A Boy and His Atom" on the Topic 2.4 opening spread are about 120 pm, or 0.000 000 000 12 m, in diameter.

a) Use a ruler to measure the width of one of the atoms in the large image of the "boy." How many times bigger are the atoms on the page than the real thing?

b) Analogies in this unit compare familiar objects such as apples and the Earth or a puck and a hockey arena to help you understand the structure and size of an atom. Construct a similar analogy to help a friend understand just how small an oxygen atom is.

Thinking Critically and Creatively

18. Carbon dioxide and carbon monoxide are familiar gases with similar names. Both contain the same two types of atoms: carbon and oxygen. Both are colourless and odourless. The density of carbon dioxide is 1.96 g/L, and the density of carbon monoxide is 1.25 g/L. Carbon dioxide puts out flames and does not burn in air or in pure oxygen. Carbon monoxide burns easily in air and pure oxygen. Unlike carbon dioxide, carbon monoxide combines with the oxygen-carrying site in red blood cells, so the blood can't hold free oxygen anymore.

a) Design a chart to compare the physical and chemical properties of carbon dioxide and carbon monoxide.

b) Suppose you have a canister of carbon dioxide and a canister of carbon monoxide. Using your knowledge of WHMIS, design a label for each.

c) Why is carbon monoxide so dangerous to human health?

19. Frozen carbon dioxide is called "dry ice." It is used in a number of ways, including as a coolant for transporting organs and blood, and as a way to make ice cream quickly. Unlike water, at room temperature solid carbon dioxide changes directly into a gas.

a) Why do you think frozen carbon dioxide is also called dry ice?

b) The freezing temperature of dry ice is –56.6°C. Why is dry ice a more effective coolant than ice?

c) Name the change that dry ice undergoes at room temperature. Draw diagrams to model what is happening to the carbon dioxide particles according to the kinetic molecular theory.

d) When placed in water at room temperature, dry ice changes to a gas much more quickly than it would in air at the same temperature. A dense fog is produced consisting of condensed water droplets. Why does adding dry ice to water increase the speed of the change?

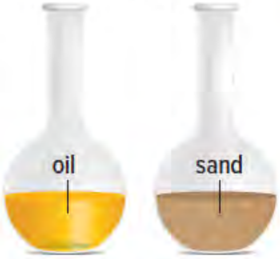
e) What safety precautions do you think people would need to take when handling dry ice? Give reasons for your answers.

Understanding Big Ideas

Making New Connections

Applying Your Understanding

20. Liquids take the shape of their containers. The diagram below shows sand, which is a solid, taking the shape of its container. Does this mean that sand is a liquid? Explain why or why not in terms of the kinetic molecular theory.



21. For a chemical change to take place, atoms must interact. For atoms to interact, they must come into contact with one another. Which subatomic particle do you think plays the most important role in chemical changes of matter? Justify your response.

Thinking Critically and Creatively

22. Suppose your teacher asks, "What happens to the temperature of water as it changes state?"

a) Suggest at least two questions to ask in order to clarify your teacher's question.

b) Choose one of your clarifying questions. State two hypotheses in the form of "If…then…" statements that address this question.

c) Briefly outline a procedure that could be used to test one hypothesis.

d) Describe the methods you would use to record the data you would be able to collect from your experiment.

e) Predict what you would discover if you carried out your experiment.

Connecting to Self and Society

23. Design a one-page quick reference guide for the general public about how to identify, handle, and dispose of household hazardous material. As part of the design, consider the following:

- ability to be quickly scanned for information
- visual appeal
- persuasiveness
- needs of the target audience

24. In 1996, a high school student wrote a science fair report about a chemical called dihydrogen monoxide. Some of its properties included the following:

- It is a key ingredient in most pesticides.
- It can cause painful burns to skin.
- It can cause illness and even death in either very low or very high amounts in the body.
- It contributes to most environmental problems and weather-related disasters.

Most of the people who read the report were so alarmed that they agreed the chemical should be banned.

a) Assuming the above properties are true, do you agree that the chemical should be banned? Is there additional information that you would like before you decide? Explain your answer.

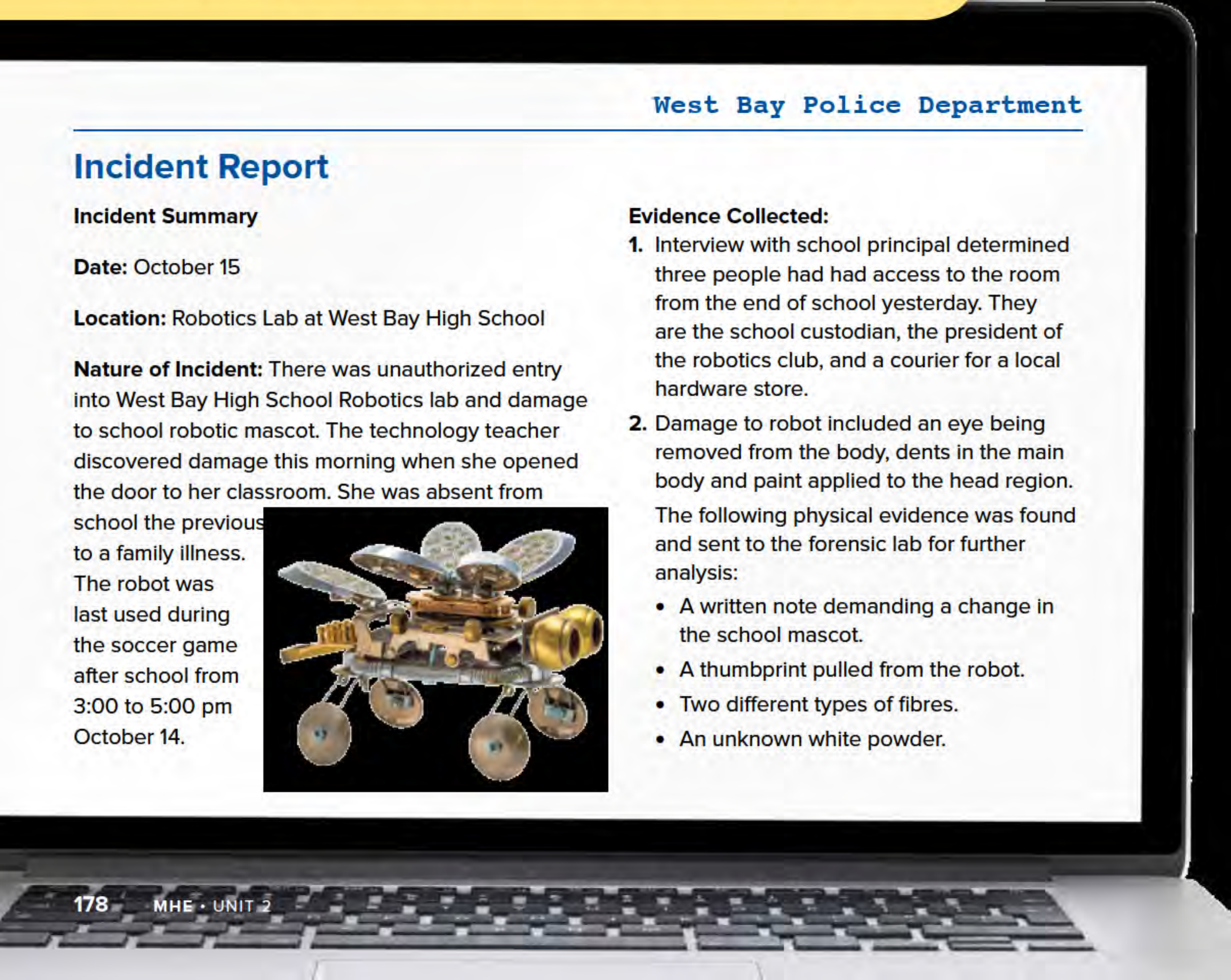
b) Find out the common and standard chemical names for dihydrogen monoxide. Does your perspective change? Explain.

c) Issues about dangerous chemicals are often reported on the Internet. List some questions you might ask to help you decide if an issue is being represented fairly or if it is being misrepresented.

Unit Assessment

Who Broke the West Bay High School Soccer Robotic Mascot?

West Bay High School is known for two things: soccer and robotics. So, of course it makes perfect sense that the students would figure out that the best way to cheer on their soccer team is to create a robotic mascot. The mascot known as "Westie", both at school and in the city, has friends throughout the West Bay region. Unfortunately, there's been a terrible event and "Westie" has been broken. Below you will find the evidence collected by the West Bay City Police. As the investigation is ongoing, more evidence will be released soon. Students of West Bay High and residents of West Bay are looking for answers and they want them quickly.



West Bay Police Department

Incident Report

Incident Summary

Date: October 15

Location: Robotics Lab at West Bay High School

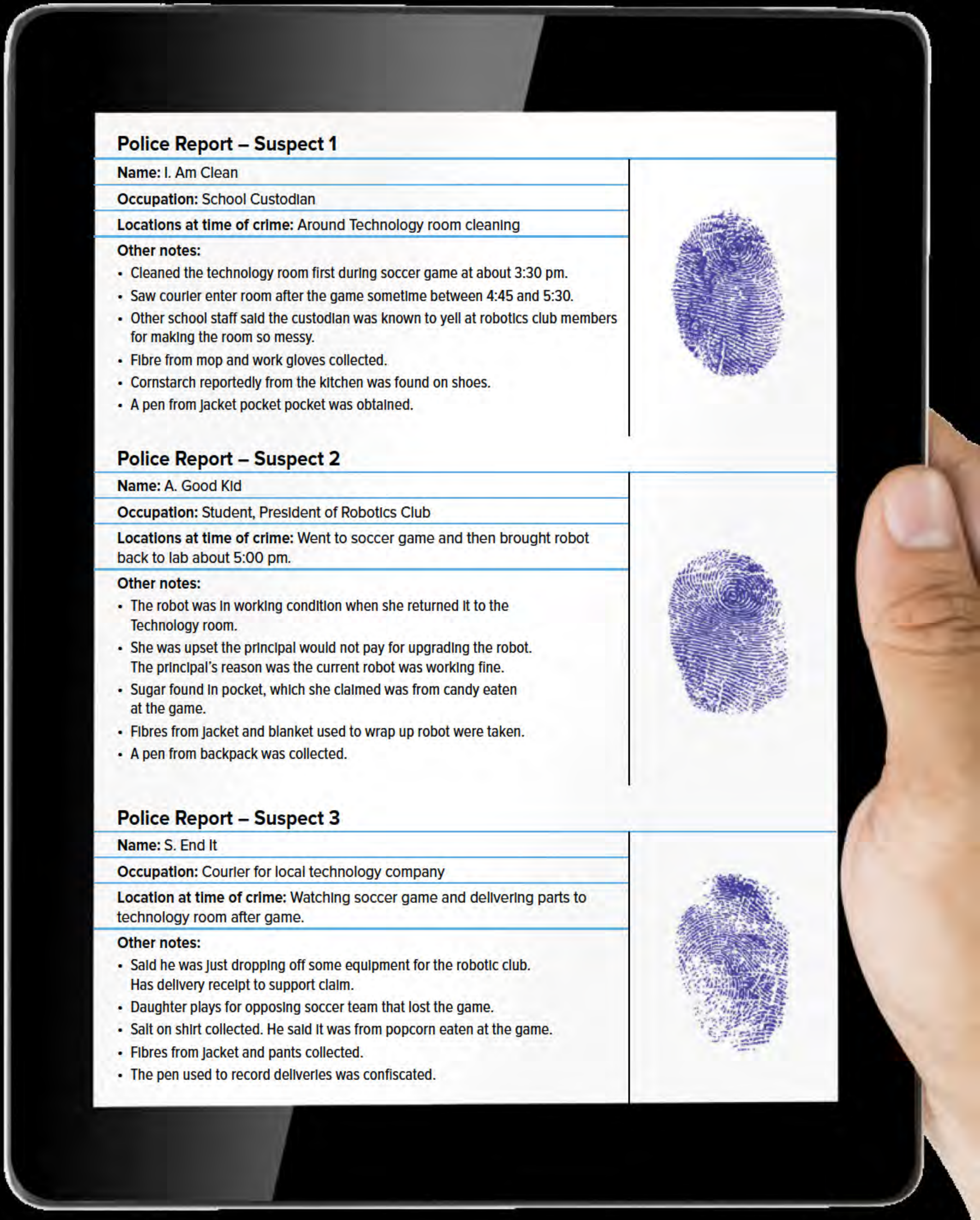
Nature of Incident: There was unauthorized entry into West Bay High School Robotics lab and damage to school robotic mascot. The technology teacher discovered damage this morning when she opened the door to her classroom. She was absent from school the previous to a family illness. The robot was last used during the soccer game after school from 3:00 to 5:00 pm October 14.

Evidence Collected:

1. Interview with school principal determined three people had had access to the room from the end of school yesterday. They are the school custodian, the president of the robotics club, and a courier for a local hardware store.
2. Damage to robot included an eye being removed from the body, dents in the main body and paint applied to the head region.

   The following physical evidence was found and sent to the forensic lab for further analysis:

   - A written note demanding a change in the school mascot.
   - A thumbprint pulled from the robot.
   - Two different types of fibres.
   - An unknown white powder.



Police Report – Suspect 1

Name: I. Am Clean

Occupation: School Custodian

Locations at time of crime: Around Technology room cleaning

Other notes:

- Cleaned the technology room first during soccer game at about 3:30 pm.
- Saw courier enter room after the game sometime between 4:45 and 5:30.
- Other school staff said the custodian was known to yell at robotics club members for making the room so messy.
- Fibre from mop and work gloves collected.
- Cornstarch reportedly from the kitchen was found on shoes.
- A pen from jacket pocket pocket was obtained.

Police Report – Suspect 2

Name: A. Good Kid

Occupation: Student, President of Robotics Club

Locations at time of crime: Went to soccer game and then brought robot back to lab about 5:00 pm.

Other notes:

- The robot was in working condition when she returned it to the Technology room.
- She was upset the principal would not pay for upgrading the robot. The principal's reason was the current robot was working fine.
- Sugar found in pocket, which she claimed was from candy eaten at the game.
- Fibres from jacket and blanket used to wrap up robot were taken.
- A pen from backpack was collected.

Police Report – Suspect 3

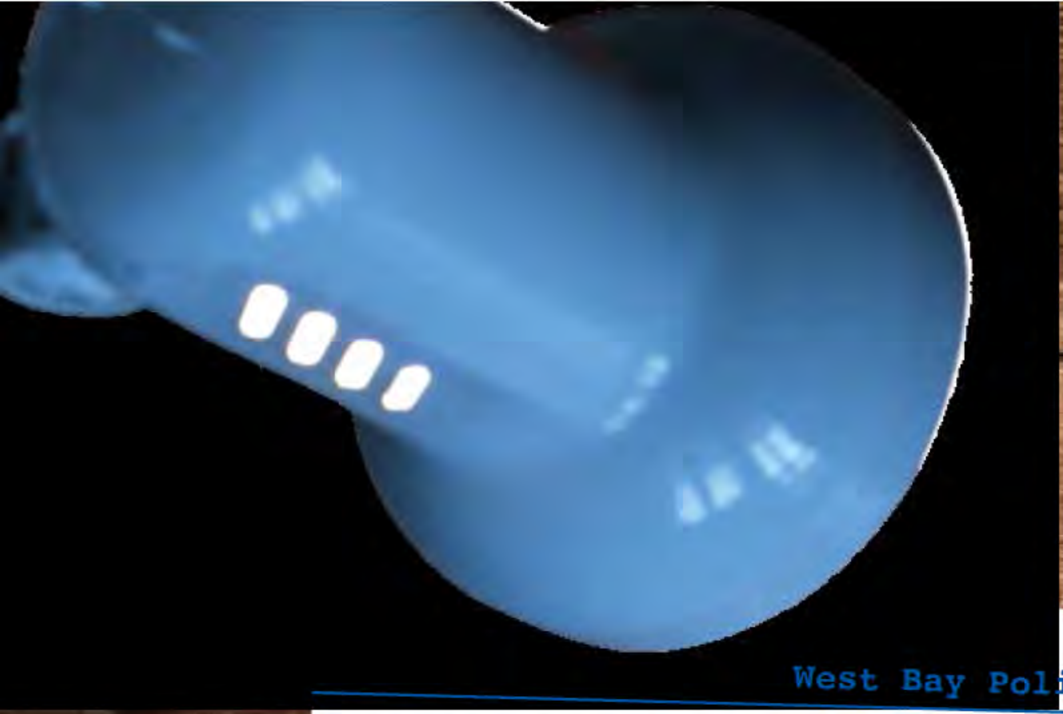
Name: S. End It

Occupation: Courier for local technology company

Location at time of crime: Watching soccer game and delivering parts to technology room after game.

Other notes:

- Said he was just dropping off some equipment for the robotic club. Has delivery receipt to support claim.
- Daughter plays for opposing soccer team that lost the game.
- Salt on shirt collected. He said it was from popcorn eaten at the game.
- Fibres from jacket and pants collected.
- The pen used to record deliveries was confiscated.

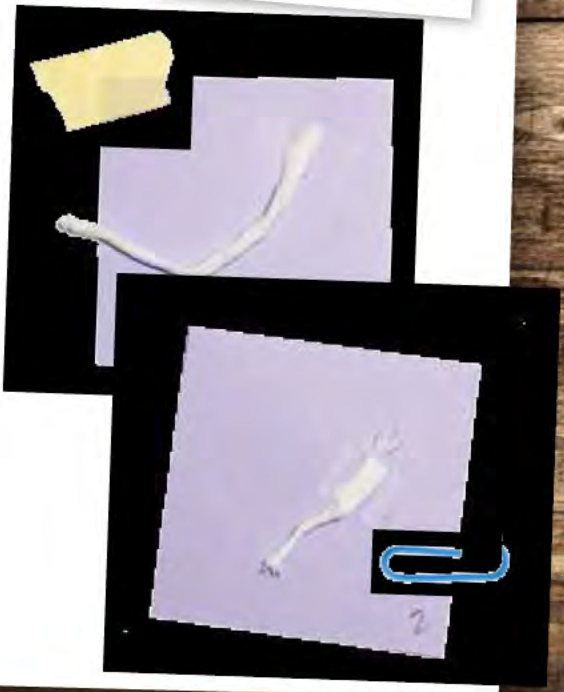


West Bay Police Department

Forensic Lab Report –
Preliminary Report

Fingerprint Analysis
A thumbprint was collected from a broken wheel of the robot. Other partial prints were found on the body of the robot, but the forensic technician was only able to lift a thumbprint.

Fibre Analysis
Two fibres were collected at the scene of the incident. As the robot is made of metal, collection was relatively easy. Note that the robot was also somewhat dirty as blades of grass and dirt from the soccer field were found on the wheels and underside.

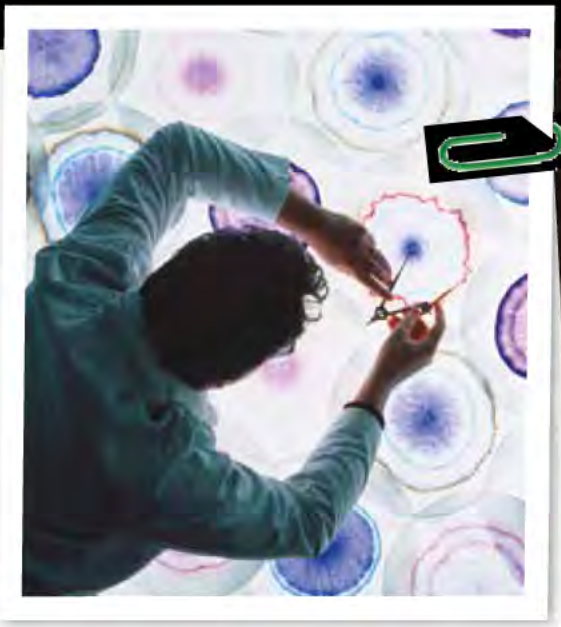


West Bay Police Department

Forensic Lab Report – Preliminary Report (cont'd)

Pen
The ink from the note that was found at incident scene was tested using chromatography. The resulting chromatogram is due back from the lab any time now.

White Powder
The white power collected at the incident scene was sent to a chemical laboratory for further analysis. The report is due back today.



Your Task

Your teacher will start the TimeStamp™ video when the task begins. Your task is to analyze the evidence and determine which of the three suspects broke "Westie" the Robotic Mascot. Use what you have learned about matter and the skills you have developed during various activities in this unit to find an answer you can support with evidence. Also demonstrate how the evidence shows the other two suspects are innocent.

TOPIC 2.1

How does matter affect your life?

Key Concepts

- Everything—including you—is made up of chemicals.
- Chemicals in your daily life have characteristics that make them useful, hazardous, or both.
- Handling chemicals and equipment safely is important at school and at work.

Curricular Competencies

- Ensure that safety and ethical guidelines are followed in your investigations.
- Experience and interpret the local environment.
- Consider social, ethical, and environmental implications of the findings from your own and others' investigations.
- Contribute to care for self, others, community, and world through personal or collaborative approaches.

What does the word "chemical" mean to you? Do you think of preservatives in food? Or bubbling liquids in beakers and flasks? These are chemicals, but a chemical is not necessarily dangerous or made in a laboratory—"chemical" means the same as the word "matter." Everything you eat, everything you wear, the air you breathe, a cell phone, a bicycle, a tree, a cat, the Sun, the planets—even you are made up of matter.

Most of the matter that you handle and come in contact with every day is safe. However, many types of matter, even things that are useful or familiar, can be hazardous. To stay safe when working with matter, it is important to know about those hazards and how to avoid them. We do this by learning how to read information labels and how to properly handle the matter we work with.

[redacted]

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** List five examples of matter that you relied on today. For each one, explain why you think it is matter. Based on your answers, come up with your own definition of matter.
2. **Evaluating** Most kitchens at home today have at least some products made with plastics. Think about containers, for example. Plastic products for the home began to become widely available during the 1950s. Before then, people used materials such as glass, paper, and metal to wrap or hold food.
   - **a)** What characteristics make glass, paper, and metal suitable for containers?
   - **b)** What characteristics make plastic a desirable substitute for these materials?
   - **c)** What are some undesirable characteristics of plastic?
3. **Communicating** Assume you have been asked to interview a member of the health and safety committee in your school about how hazardous materials are handled in the school and what safety practices are in place. Make a list of questions you want to ask this person.

Key Terms

There is one key term that is highlighted in bold type in this Topic:

- matter

Flip through the pages of this Topic to find this term. Add it to your class Word Wall along with its meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Everything—including you—is made up of chemicals.

Activity

Is It Really Chemical-Free?

Consider the statements below.

- A company that makes environmentally friendly products makes a cleaning cloth that kills bacteria and other germs. The cloth contains tiny bits of silver. The company says, "Silver is a metal, not a chemical."
- Many gardeners proclaim their lawns and gardens are chemical-free. Their results depend on methods that include the use of natural fertilizers such as manure and nutrient-rich compost.

Now work together in small groups to answer the following questions.

1. What do you think "chemical-free" means, according to these statements?
2. Is it possible for any product to be chemical-free? Explain.

Do you think of yourself as being chemical-free? Think again. **Figure 2.1** shows that you are made up mostly of four types of chemicals called elements, with smaller amounts of many, many others.

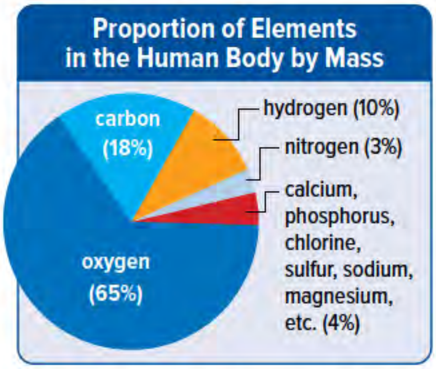


Figure 2.1 All people are made up mostly of oxygen, carbon, hydrogen, and nitrogen. Where do we get the chemicals we need for our bodies?

Often the term "chemical" is used to refer to certain substances or mixtures of substances, such as oxygen or salt water. However, the word "chemical" does not have a specific scientific meaning. That's because everything in the world that isn't energy is a chemical or contains chemicals. When people use the word "chemical," they are really talking about matter. Anything that takes up space and has mass is called **matter**.

matter anything that has mass and takes up space

Before you leave this page . . .

1. In your own words, define the term "matter."
2. What kinds of misunderstanding can result when people use the word "chemical" when talking about issues involving health and the environment?

CONCEPT 2

Chemicals in your daily life have characteristics that make them useful, hazardous, or both.

Activity

Common Sense Safety

Many of the products you use at home can be dangerous if not handled properly. That's why there are guidelines for using them. Copy the table and add rows for propane, soap, mouthwash, and paint. Add three more of your choice. Complete the table.

Chemicals in the Home

Matter	Useful Characteristics	Hazardous Characteristics	Rules for Handling
cleaning products	kill bacteria and other germs	can burn skin and are poisonous	use in a well-ventilated area, avoid contact with skin

Chemical Safety Around the House

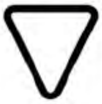
Many products have symbols on them to warn of possible danger. The Hazardous Household Products Symbols (HHPS) give safety information about a product (Figure 2.2). Each symbol provides two kinds of warnings:

- whether the hazard is the container or the contents
- the type of hazard—explosive, corrosive, flammable, or poisonous

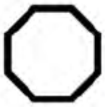
Connect to Investigation 2-A on page 107

Figure 2.2 Household hazardous product symbols are used on warning labels on many consumer products. **Name two products with HHPS on their containers.**

The Borders

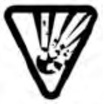


Dangerous Container
The border that looks like a traffic yield sign means that the container is dangerous.

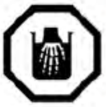


Dangerous Product
The border that looks like a traffic stop sign means that the contents of the container are dangerous.

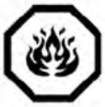
The Hazards



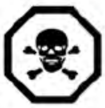
Explosive
This symbol means that the container can explode. If it is punctured or heated, pieces can cause serious injuries, especially to the eyes.



Corrosive
This symbol means that the product inside the container will burn the throat or stomach if swallowed and will burn skin or eyes on contact.



Flammable
This symbol means that the product will catch on fire easily if it is near sparks, flames, or even heat.



Poisonous
This symbol means that the product will cause illness or death if you eat or drink it. For some products, just smelling or licking them is enough to cause serious harm.

Before you leave this page . . .

1. What is the HHPS system? Why is it used?
2. Which HHPS would be on spray paint?

AT ISSUE

What are the hazards of pretty packaging?

What's the Issue?

Household cleaners are big business. Every year, consumers spend billions of dollars on laundry and dishwasher detergents alone. While people have been cleaning their clothes and dishes the same way for decades—using detergent and water—manufacturers are always coming up with new ways to try to make their products stand out.

Enter the detergent pod. These products were developed to make it easier for consumers to use the proper amount of detergent, as well as avoid messy bottles of liquid or boxes of powder. So what's the problem?

These detergent pods are small, bright, colourful tablets that resemble candy—especially to young children. But detergents can be poisonous. Since these pods went on the market, there has been a large increase in detergent-related poisonings in children five years old and younger. Should manufacturers be allowed to continue producing colourful detergent pods?

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. Read the label of a detergent package. Record the ingredients and research the hazards of those substances. As a result of your research, will you change the way you handle or think about using detergent? Explain why or why not.
2. Pod-related harm to children began to be reported very soon after the pods were available.
   a) Find out about the increases in reports of detergent pod exposure to poison control centres.
   b) What harm to children has been reported?
   c) What have companies done to address safety concerns? Do you think the problem has been solved? Explain why or why not.
3. Some people argue that pods are helpful to consumers. Companies often rely on people using too much of a product than is actually needed, prompting them to buy more, sooner. Using a pod avoids that. However, many agencies that fight for consumer safety say detergent pods are health hazards and do not support their use. Where do you stand on this issue? Make sure to support your opinion in your answer.

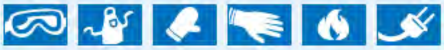
CONCEPT 3

Handling chemicals and equipment safely is important at school and at work.

Activity

Know Your Safety Icons

What do you think these six safety icons mean? Make a prediction for each, and then read Safety in Your Science Classroom on pages xiv–xvii to find out.

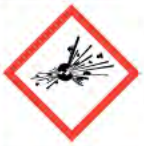
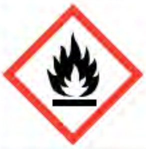
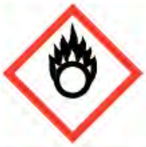
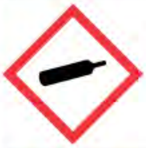
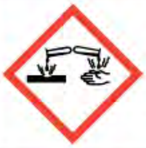
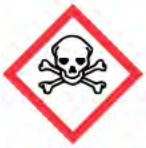
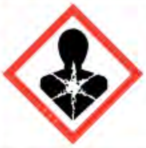
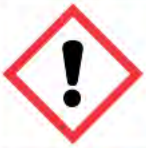
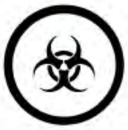


WHMIS 2015

By law, everyone in the workplace, including at school, must be informed about the chemicals they use and how to handle them safely. In Canada, this is done through the Workplace Hazardous Materials Information System, or WHMIS. WHMIS provides detailed information about how to store, handle, and dispose of chemicals. It also provides first aid information.

Figure 2.3 lists the WHMIS symbols for hazardous products. In 2015, these symbols replaced an older set of WHMIS symbols. If you look in an older science book, you may see a different set of symbols. Each chemical also has a Safety Data Sheet (SDS) associated with it. The SDS contains information about the composition and properties of a hazardous substance, as well as steps to handle and store it safely.

Figure 2.3 The WHMIS 2015 safety symbols are used throughout Canada to identify dangerous materials. **Which WHMIS symbols would you find on a container that contains a flammable gas stored under pressure?**

 **Exploding bomb** (for explosion or reactivity hazards)	 **Flame** (for fire hazards)	 **Flame over circle** (for oxidizing hazards)
 **Gas cylinder** (for gases under pressure)	 **Corrosion** (for corrosive damage to metals, as well as skin, eyes)	 **Skull and Crossbones** (can cause death or toxicity with short exposure to small amounts)
 **Health hazard** (may cause or is suspected of causing serious health effects)	 **Exclamation mark** (may cause less serious health effects or damage the ozone layer)	 **Biohazardous infectious materials** (for organisms or toxins that can cause disease in people or animals)

Staying Safe in Your School Laboratory

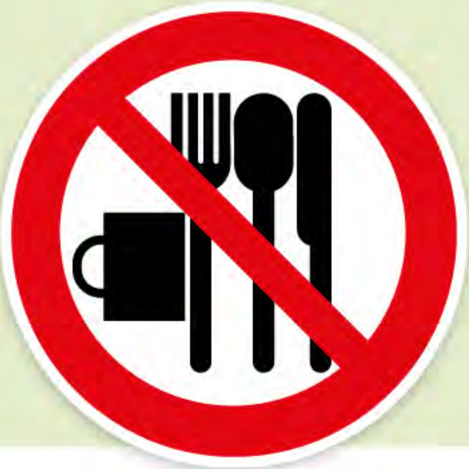
1. Before you begin

- Inform your teacher if you have any allergies or medical conditions, or if there are other factors that could affect your work in the chemistry lab.
- Know the location of the nearest fire alarm, fire extinguisher, fire blanket, first-aid kit, safety shower (if there is one), and eye wash station. Know how to use them.
- Study your activity, investigation, or other lab assignment carefully before you start. Ask for help if you have questions.
- Be sure you understand the safety icons.

FIRE
BLANKET

2. Dressing the part

- Wear protective clothing as appropriate and as directed, such as a lab apron, gloves, and safety glasses.
- Tie back long hair, and secure or remove scarves, caps, ties, or long necklaces.
- Wear footwear that covers your entire foot, including toes.



3. Acting responsibly

- Never chew gum, eat, or drink in the lab.
- Work carefully with your partner or group and make sure you keep your work area clear.
- Stay focused on what you are doing. Acting irresponsibly is dangerous in the lab.

Safety in the Laboratory

Making sure that you know how to handle chemicals and equipment safely in the school laboratory is an essential part of your exploration of matter. You are responsible for the safety of everyone around you as well as your own. In addition to WHMIS, there are safety rules and icons you must know and follow. Some of these are shown in Figure 2.4. Also read Safety in Your Science Classroom on pages xiv–xvii of this book. Your teacher may give you additional safety rules to follow.

4. Using equipment

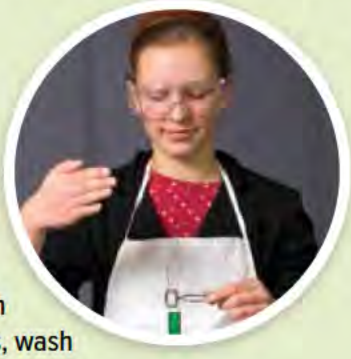
- When carrying equipment for an activity or investigation, hold it carefully. Carry only one object at a time.
- When working with electrical equipment, make sure your hands are dry, especially when touching electrical cords, plugs, or sockets. Pull the plug, not the cord.
- Report damaged equipment to your teacher immediately.
- Place electrical cords where people will not trip over them.

5. Working with heat

- If you use a laboratory burner, be sure you understand how to light and use it safely.
- Point the open end of a container being heated away from yourself and others.
- Do not allow a container to boil dry.
- Handle hot objects carefully. Remember that glassware and equipment looks the same hot as it does cold.
- Inform your teacher if you receive a burn. Apply cold water and then ice to the burned area immediately.

6. Working with chemicals

- Read and understand all safety labels, including WHMIS symbols.
- Never taste any substances you use in the lab.
- If any part of your body contacts a substance in the lab, inform your teacher. Immediately wash the area thoroughly with cold water. If you get anything in your eyes, wash them immediately and continuously for 15 minutes.
- Handle substances carefully. If you are asked to smell a substance, never smell it directly. Hold the container slightly in front of and beneath your nose, and waft the fumes toward your nostrils.



7. Cleaning up

- Clean up any spills according to your teacher's instruction.
- Clean equipment and glassware before you put it away.
- Dispose of all materials as directed by your teacher. Never discard materials in the sink or garbage unless your teacher directs you to.
- Wash your hands thoroughly after doing an activity or investigation.

Figure 2.4 These are just some of the safety rules to follow in the school laboratory. **For each category, describe a situation in a laboratory that would apply.**

Connect to Investigation 2-B on pages 108–109

Before you leave this page . . .

1. What is WHMIS and what role does it play in laboratory safety?
2. Why is it important to have a common set of safety labels and icons for hazardous chemicals in all workplaces and schools?

AT ISSUE

Who makes sure consumer products are safe?

What's the Issue?

Many of the substances we use at home have properties that make them both beneficial and dangerous. Medications are designed to improve our health, but if taken incorrectly can cause harm. Chlorine is in household cleaners and products used to keep pools safe because it kills bacteria and other microbes. But it can also harm or even kill people. If you were working with chlorine-containing chemicals in the laboratory, you would be wearing a lab coat, safety goggles, and gloves. Who is responsible for ensuring that consumers have all the information they need to stay safe when using products?

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. The Hazardous Household Products Symbols system does not cover all consumer products. For example, medications, detergents, and many cleaning agents and personal care products are not always required to display such information.
    a) Collect 10–12 consumer products that could cause harm if not used properly. Find as wide a variety as possible. Read the warning descriptions and instructions for what to do if an accident happens.
    b) What could be an alternative to descriptions of hazards and the medical attention that is needed if an accident happens?
2. Many people wonder where the responsibility lies when it comes to using consumer products safely. Some argue the responsibility is in the hands of the manufacturers who make the products to provide all the information possible. Others argue that it is each individual's responsibility to use a product properly. Divide into two groups and set up a debate regarding who should be responsible for ensuring people's safety when using consumer products.
3. WHMIS 2015 incorporates the Globally Harmonized System of classification and labelling of chemicals (GHS) for Canadian workplaces. GHS is an international initiative to make all chemical hazard classifications the same throughout the world. Why is this an important step in improving WHMIS? How could this be applied to consumer products?

Check Your Understanding of **Topic 2.1**

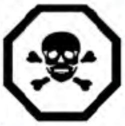
QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Steps from two different laboratory procedures are given below. Which safety icons and WHMIS symbols should be included with the procedures? More than one may apply in each case. Explain why you chose each symbol. PA E C

- Pour a solution of salt water from a graduated cylinder to a beaker.
- Light a Bunsen burner. Then gently heat the test tube containing the solution. Do not breathe in the irritating ammonia gas that forms.

2. You are about to use a household product that has this symbol on its label.



a) What does this symbol mean?

b) Describe the precautions you should take when using the product. AI PA

3. Make a sketch of your science lab or classroom showing the location of emergency exits, eye wash stations, fire extinguishers, and any other emergency equipment. Include the name of your school's emergency first aid contact. C

Connecting Ideas

4. Suppose you are a writer for the local community newsletter. You have been asked to interview someone at the fire department about how they deal with hazardous chemicals. Come up with a list of questions you have for the person you are interviewing. C QP

5. Name three jobs that require a person to know about chemicals, their possible dangers, and how to work with them safely. Describe the type of chemical knowledge each job needs. QP C PA

6. Many homes have hazardous materials. Often, people dispose of them by throwing them out in the regular garbage or flushing them down drains or toilets. QP C AI

a) What hazards are associated with these practices?

b) Write a public service announcement to advise people of the dangers of hazardous household products and why they should not be disposed of in this way.

c) Come up with an idea for how your local city or town council could deal with hazardous waste.

Making New Connections

7. The term "green chemistry" refers to an area of chemistry that involves designing consumer products and the methods used to make them so that less hazardous material is involved. AI C QP

a) In what other way have you seen or heard the term "green" being used? What does the word mean when it is used that way?

b) It takes time and money for a company to change how it produces a product to make it greener. Assume you are an environmental consultant who must convince a chemical company to switch to green chemistry. Make a list of important points you will make to do this.

TAKE Action

Make a Difference

Reducing Hazardous Waste

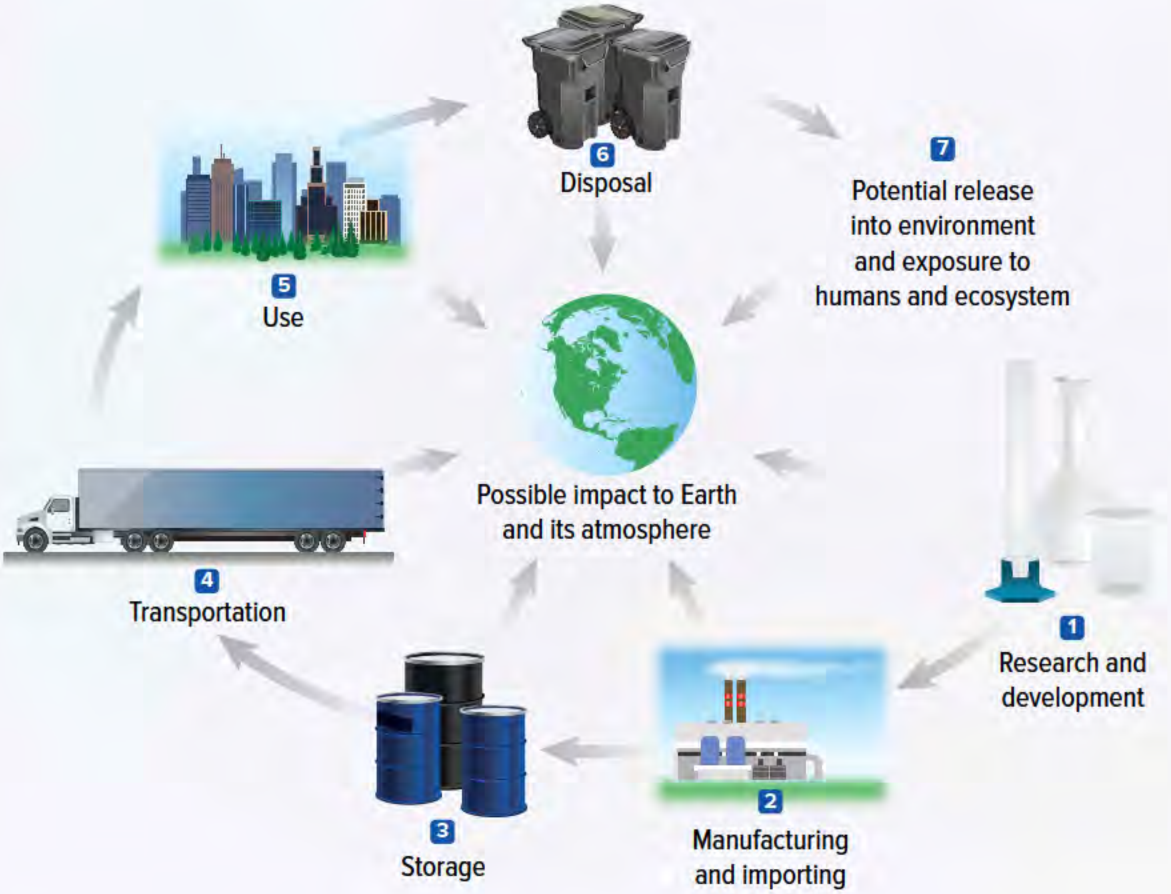
A product's life cycle includes all the steps in making, distributing, selling, using, and disposing of the product. Hazardous materials are used and eventually become waste at many points in the life cycle of many products.

Through our own actions, including the choices we make about the products we buy, we contribute to hazardous waste in Canada. In total, Canadians generate more than 6 000 000 t (tonnes) of hazardous waste each year.

What We Can Do

Ways to prevent hazardous waste from entering the environment include the following.

- **Reduce hazardous waste.** People can choose to buy products made by methods that reduce


1
Research and development
2
Manufacturing and importing
3
Storage
4
Transportation
5
Use
6
Disposal
7
Potential release into environment and exposure to humans and ecosystem
Possible impact to Earth and its atmosphere

hazardous waste. Wastes can also be reduced if people buy only the amount of product they expect to use. Some hazardous substances can be replaced with less harmful substances that do the same job.

- **Recycle hazardous waste.** E-cycling programs help keep electronic waste (e-waste) out of the environment. Through e-cycling, electronic devices may be redistributed to charities for further use. If they can't be re-used, the devices are dismantled and their parts sold for use in other applications.
- **Dispose of hazardous wastes properly.** Home garbage ends up in landfill sites, which means any hazardous materials end up being dumped directly onto the land. Hazardous liquids poured down the drain in homes and schools end up back in the environment. Different regions have household hazardous waste drop-off sites. Schools have established procedures for disposing of liquid and solid hazardous wastes.

Planning Your Hazardous Waste Reduction

Your task is to develop a public awareness campaign about how we can prevent hazardous wastes from entering the environment. Research how your friends, your classmates, your family, and your school deal with hazardous waste. Research different ways that schools and communities in B.C. have addressed this issue.

Questions to consider when developing your campaign can include the following.

- Who will your target audience be—the whole community or students in your school?
- How will you communicate the information?
- What information do you need to research?
- How will you grab people's attention?
- How will you get people to change their habits and make extra effort to deal with their hazardous waste or change the products they buy?
- How will you assess how successful your campaign was?

Analyze and Evaluate

1. Do you consider your campaign a success? What is your evaluation based on?
2. Describe any challenges you had with developing or running the campaign. What would you do differently, if you ran such a campaign again?

Apply and Innovate

3. Suppose your local council has heard about your campaign to reduce hazardous waste and is considering expanding it. They have asked you to present the information in a meeting with council members. Develop a presentation for the council that informs them about the issue and your campaign, and includes suggestions for expanding the campaign to reach your entire town, city, or area.

SCIENCE AT WORK

Chemistry Connections

What kinds of jobs are there for people who work with matter?

- Research Scientist
- Paramedic
- Geologist
- Chemical Engineer
- Environmental Chemist

Analytical Lab Technician

If you're a stickler for detail, like working with chemicals and lab equipment, and want a range of employers to choose from, check out work as an analytical lab technician.

ISO 14000 Consultant

Want a profession few people have probably heard of? ISO 14000 is a set of standards for minimizing environmental impact. ISO 14000 consultants help companies comply with the standards.

Pharmacist

Pharmacists are more than mere dispensers of medicine. They are health care collaborators, linking doctors, patients, families, and communities in the service of wellness.

Questions

1. What other jobs and careers do you know or can you think of that involve chemistry?
2. Research a job or career that interests you and involves the study of matter. What essential knowledge, skills, and aptitudes are needed? What are the working conditions like? What attracts you to this job or career?

INVESTIGATION

2-A

GUIDED INQUIRY

A Survey of Hazardous Materials in Your Home

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Do not carry out your plan until your teacher approves it.
- Do not conduct your survey without an adult present.

What You Need

- paper and pencil
- rubber gloves

In this investigation, you will identify and list the hazardous materials at your home.

Question

What hazardous materials are in your home, and where are they located?

Procedure

1. Make a plan for how you will conduct the survey of your home. Use the following questions to guide you.
   - How will I determine if an item is hazardous and what type of hazardous material it is?
   - What safety precautions will I take?
   - What information will I collect and how will I record my findings?
2. Have your teacher approve your plan.
3. Arrange a time when a parent or guardian can accompany you during your survey.
4. Do not handle containers that are damaged, and make sure to wash your hands when you are finished.

Analyze and Interpret

1. Did any findings from your survey surprise you? If so, explain why.
2. Did one area of the home contain more hazardous substances than others? If so, which area was it?

Conclude and Communicate

3. Compare your survey with those of your classmates.
4. Propose two ways to reduce the amount of hazardous materials in your home.
5. Do research to find less-hazardous alternatives that could replace two hazardous products in your home.

INVESTIGATION

2-B

STRUCTURED AND GUIDED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- Safety in Your Science Classroom on pages xiv–xvii
- Internet access
- print sources of information on WHMIS 2015
- several sample SDS
- sample chemical bottles from the lab

Practise Safety in the Laboratory

Learning how to work safely in the laboratory is an essential part of studying chemistry. Mastering these skills will allow you to enjoy investigating science for years to come. In this investigation, you will practise working with WHMIS symbols and laboratory safety procedures.

Question

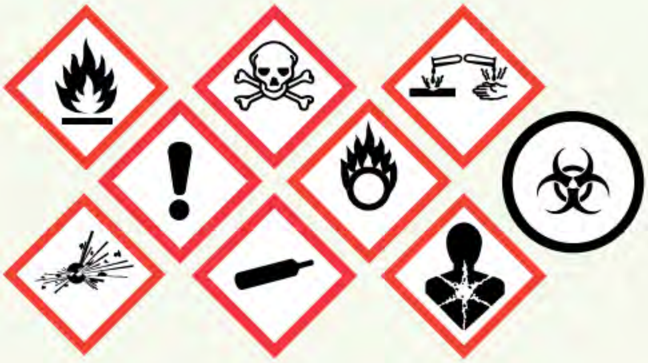
What safety-related information is important when working in a laboratory?

PROCEDURE

Part A (Structured): WHMIS 2015

Answer the following questions about WHMIS 2015. Use online or print information sources as needed.

1. Describe the basic structure of the WHMIS 2015 program.
2. Why is the program now called WHMIS 2015, instead of just WHMIS?
3. What is an SDS and what information does it provide?
4. Nine WHMIS symbols are shown below.
   a) Describe what each means.
   b) For each symbol, give one example of a substance or material that would have it on the label.



5. Choose one chemical in the laboratory.
    a) Describe the information on the label and what any symbols mean.
    b) Read the SDS. Describe how you would handle the chemical if you needed to use it for an investigation.

Part B (Guided): Safe Practices

1. With a partner, develop a method that students could use to quiz each other about the safety symbols and safety procedures used in this book.
2. Exchange the method you developed in Step 1 with another set of lab partners. With your partner, use the method from your classmates to quiz each other on the safety symbols and procedures.

Process and Analyze

1. Why is it important to know the location of safety equipment in the laboratory before you start an investigation?
2. Why is tying back long hair a safety procedure in a laboratory?
3. When should a student wear safety glasses?
4. Why should a student not eat or drink in the laboratory?
5. Chemical safety in the laboratory is important. However, there are other hazards associated with laboratory work. List three hazards you might find in a chemistry lab besides chemicals. How would you avoid each hazard?

Apply and Communicate

6. Assess the method you used for quizzing your partner on safety procedures. What improvements could you make?
7. Write a brief statement to summarize why it is important to follow safety procedures in the school laboratory.
8. Design and produce a pamphlet (or other medium) to help educate a grade 6 student about how to work safely in the laboratory. Consider including some of the following features:
    - a cartoon showing what not to do
    - a list of do's and don'ts
    - a list of age-appropriate links for learning more about chemical safety

TOPIC 2.2

What are some ways to describe matter?

Key Concepts

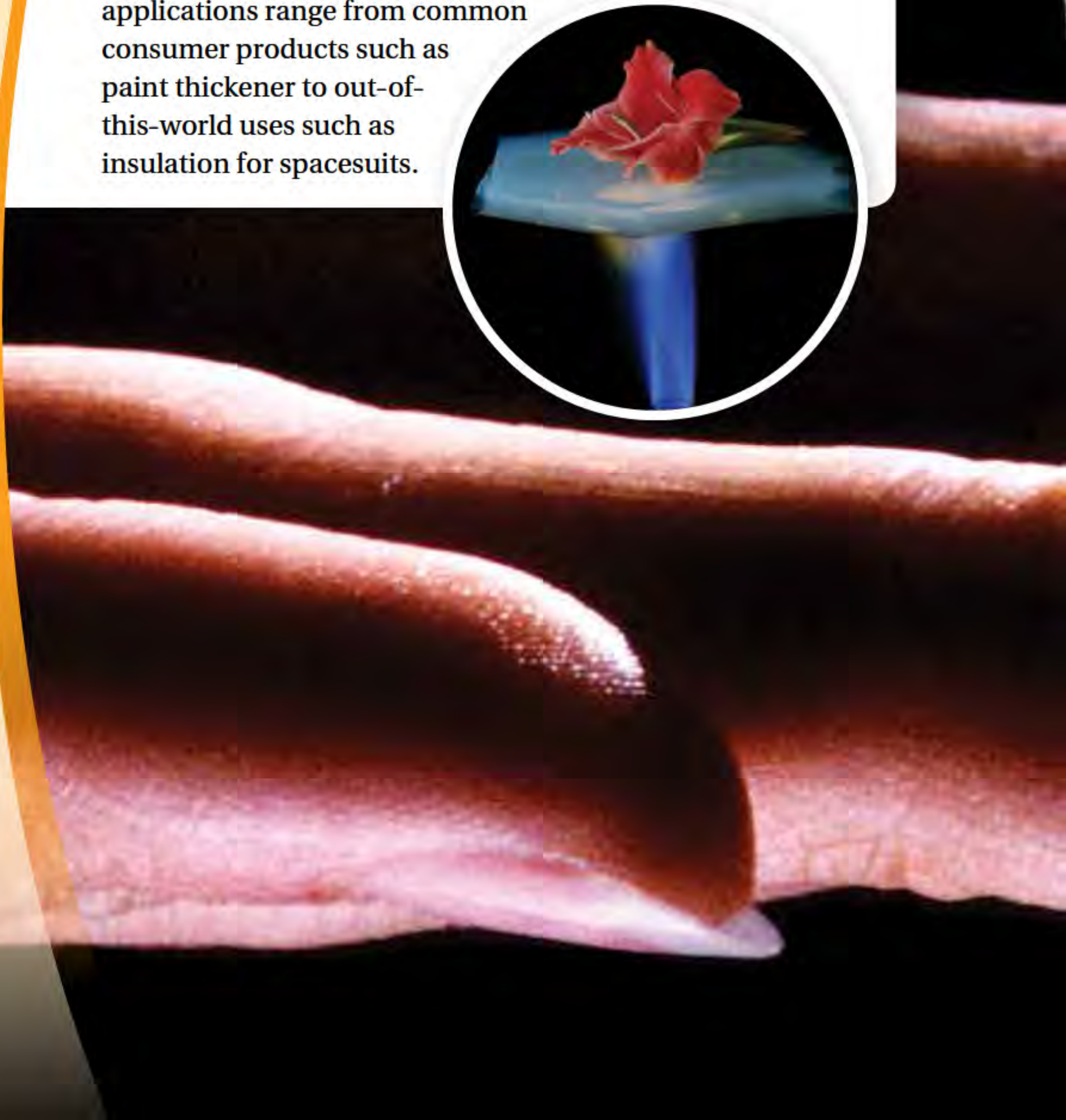
- Matter can be described by its physical properties.
- Matter can be described by its chemical properties.
- Matter can be described based on physical and chemical changes.
- Matter can be classified based on how it responds to physical and chemical changes.

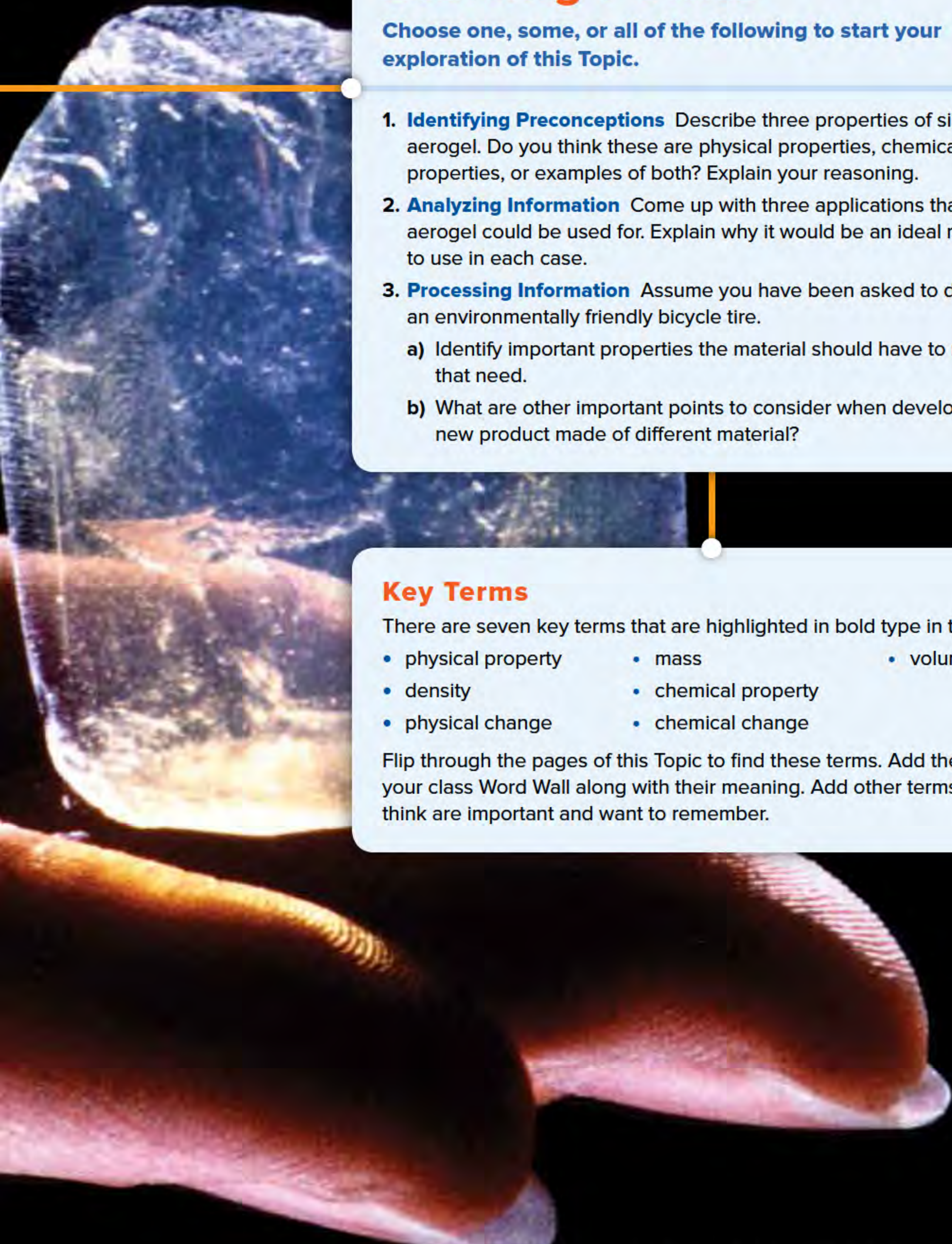
Curricular Competencies

- Identify a question to answer or a problem to solve through scientific inquiry.
- Make predictions about the findings of your inquiry.
- Demonstrate an understanding and appreciation of evidence (qualitative and quantitative).

Do these images look like they have been digitally enhanced? They haven't been. This ghostly looking material is called silica aerogel. Compared with any other solid of the same size and shape, it is extremely light. That is why it almost appears to float above this person's fingers. A cube of silica aerogel measuring 1 cm on each side is about the same size as a mini-marshmallow but is 30 times lighter.

Silica aerogel has some unique properties. Despite seeming so fragile, it has an amazing ability to insulate against heat. Even a thin piece can protect a delicate flower from the full heat of a laboratory burner. Its applications range from common consumer products such as paint thickener to out-of-this-world uses such as insulation for spacesuits.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Describe three properties of silica aerogel. Do you think these are physical properties, chemical properties, or examples of both? Explain your reasoning.
2. **Analyzing Information** Come up with three applications that silica aerogel could be used for. Explain why it would be an ideal material to use in each case.
3. **Processing Information** Assume you have been asked to develop an environmentally friendly bicycle tire.
   - **a)** Identify important properties the material should have to meet that need.
   - **b)** What are other important points to consider when developing a new product made of different material?

Key Terms

There are seven key terms that are highlighted in bold type in this Topic:

- physical property
- density
- physical change
- mass
- chemical property
- chemical change
- volume

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Matter can be described by its physical properties.

Activity

Observing Properties

Choose an object in the classroom. Write down as many of its properties as you can. Then trade your description with a partner and see if you can identify the object. Afterwards, reflect on which properties helped to make the object more or less difficult to identify.

physical property
characteristic of matter that can be observed or measured without changing its chemical identity

All matter has different characteristics that can be used to describe it. A **physical property** of matter is a characteristic that can be observed or measured without changing its chemical identity (the type of matter that it is).

Physical Properties

Qualitative Physical Properties

These berries, all B.C. crops, each have distinct colours, flavours, and odours due to a variety of substances in each fruit.

Texture is a physical property that describes how the surface of a substance feels. This sandpaper has a rough texture.

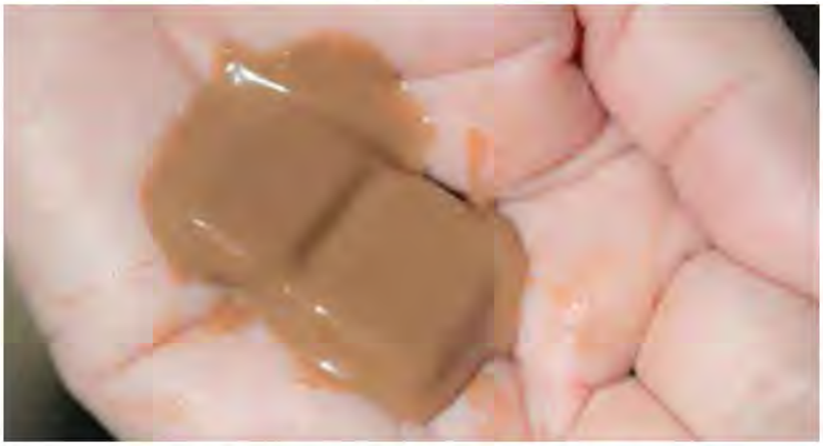
This gold ring was made by Haisla artist Barry Wilson. Gold is popular for jewellery because it is lustrous (shiny) and malleable (easy to shape). Diamond is prized for its sparkle and hardness.

Oxygen is a gas at room temperature. The state of a substance—gas, liquid, or solid—is a physical property.

Figure 2.5 shows examples of physical properties of matter. *Qualitative physical properties* can be described and compared using words, such as "red," "sweet-smelling," or "shiny." You do not need to use an instrument to make measurements when observing qualitative physical properties. However, many physical properties have numerical values associated with them. Those properties that can be measured and assigned a value are called *quantitative physical properties*.

Figure 2.5 Matter can have a variety of physical properties.

Quantitative Physical Properties



The temperature at which a substance melts is called the melting point. The melting point of most chocolates is between 30°C and 32°C, which is less than normal human body temperature.

The boiling point is the temperature at which a liquid becomes a gas. The boiling point of water is 100°C.

Solubility is the amount of matter that dissolves in another kind of matter. The solubility of table salt in water is 0.4 g of salt in 1 mL of water.

Tlingit Haida master carver Nathan Jackson uses the difference in hardness between wood and steel in his work. Various hardness scales are used to associate a number with the hardness of a material.

Viscosity describes the rate at which a material flows. Molasses has a high viscosity, which means it flows very slowly. Depending on the type, molasses is 5000 to 10 000 times as viscous as water.

Mass and Volume

mass quantity of matter in an object or sample

All matter has two things in common: mass and volume. **Mass** is the quantity of matter in a sample that is being measured. A balance is used to measure mass, and there are a variety of different types. Figure 2.6 shows two electronic digital balances in use. Some common units for measuring mass are the kilogram (kg), gram (g), and milligram (mg).

volume amount of space a substance takes up

Volume is the amount of space that a material takes up. Most often, the volume of a solid is measured in cubic units, such as cubic metres (m^3) or cubic centimetres (cm^3). The volume of a gas or liquid is measured in litres (L). Small volumes are often recorded as millilitres (mL). The unit used to measure the volume of a solid is related to the unit of volume used to measure liquids and gases. One cubic centimetre is the same volume as one millilitre ($1\ cm^3 = 1\ mL$).

Density—A Physical Property Related to Mass and Volume

Suppose you have two identical shopping bags. One is filled with loaves of bread and hotdog buns, and the other is filled with containers of juice and milk. Which would be easier to lift? Even though both bags are the same size, the second bag would be much heavier because it contains more mass in the same volume. This example describes a quantitative physical property called density.

density quantity of mass in a certain volume of material

Density is the mass of a material that occupies a certain volume. Common units of density are grams per cubic centimetre (g/cm^3) for solids and grams per millilitre (g/mL) for liquids and gases. Figure 2.6 compares two items with different densities.

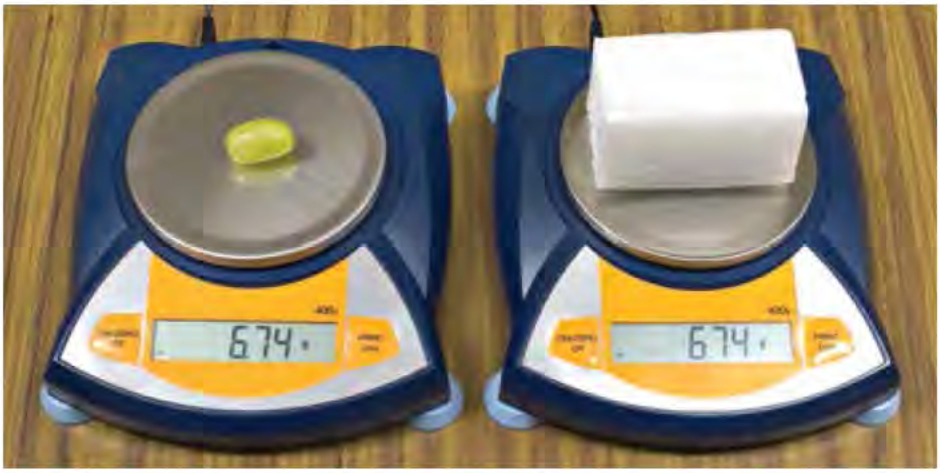


Figure 2.6 The grape and foam have the same mass but different volumes. Which substance has the greater density? Explain why.

Determining Density

You do not usually measure density directly. Instead, you measure the mass and volume of a sample and then calculate density using this equation:

Density Equation

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

For example, jet fuel is tested to ensure it meets certain standards. One standard is density. If a sample of jet fuel has a mass of 8.30 g and a volume of 10.3 mL, what is its density?

mass = 8.30 g

volume = 10.3 mL

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{8.30\ \text{g}}{10.3\ \text{mL}} = 0.806\ \text{g/mL}$$

The density of water is about 1 g/mL. Therefore, the density of the jet fuel is less than the density of water. Jet fuel and water do not mix, so when jet fuel is added to water, it forms a layer that floats on top of the water. Figure 2.7 shows how liquids with different densities can form layers in a container.

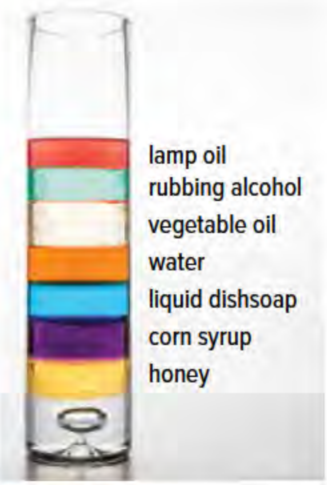


Figure 2.7 These liquids have different densities. (Dyes were added to the liquids to help you see the layers.) **List the liquids in the order of most dense to least dense.**

Activity

Finding Density

Your teacher will provide you and a partner with a set of cubes of different materials.

- Using a ruler, measure the volume of each cube. What units will you use?
- Measure the mass of each cube. What units will you use?
- Determine the density of each cube. Make sure to report it in the correct units.

Which material was the densest? Which material was the least dense?

Before you leave this page . . .

1. What is a physical property? Give three examples as part of your answer.
2. What is the difference between a qualitative property and a quantitative property?

AT ISSUE How can small floating cards help in the study of oil spills?

What's the Issue?

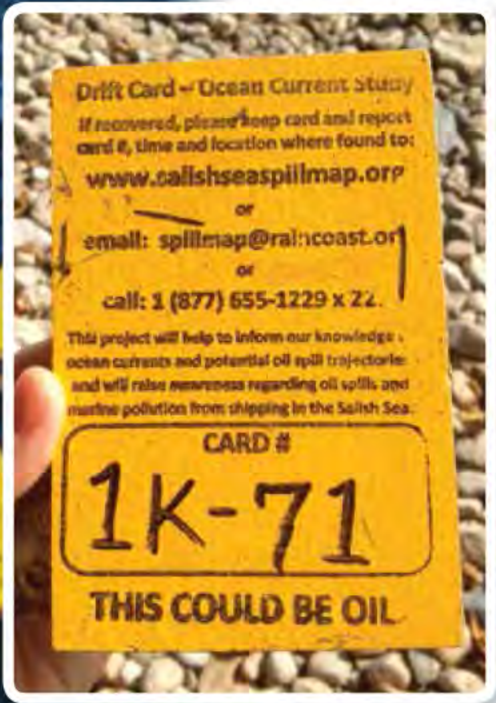
"This could be oil" was the warning that Andy Rosenberg printed on 400 yellow plywood cards. Then in October 2013 and again in August 2014, Rosenberg, a biologist with Raincoast Conservation, dumped the cards over the side of a boat. He dropped 400 into British Columbia's lower Fraser River, 600 into the Burrard Inlet, and about 3000 others in various locations off the coast of B.C.

Why would a biologist do this?

In 2013, 300 000 barrels of gas and oil were shipped every day through a vast pipeline running from the oil sands in Alberta to refineries and terminals in Vancouver, B.C., and in Washington, in the United States. Then the pipeline company decided it wanted to expand its project by adding a new pipeline. A segment of this new pipeline would carry oil under the Fraser River, in B.C. The addition of a new pipeline would increase the amount of gas and oil transported each day to 890 000 barrels.

In years past, the oil was mainly kept for local use. Now, the plan was for oil tankers to carry the oil to other destinations. The tankers would travel along many kilometres of coastline through the Strait of Georgia, Puget Sound, and the Strait of Juan de Fuca, which together are known as the Salish Sea, before reaching the Pacific Ocean. The new pipeline would increase the number of tankers moving through the Salish Sea from 4 to 35 per month.

When Andy Rosenberg, the biologist, learned of this, he was concerned. What if there were a leak in the pipeline under the Fraser River or in any of the oil tankers moving along the coastal waters? Because oil does not mix with water and is less dense than salt water, spilled oil floats and spreads out very thinly on the surface of the water. The spills can cover large areas and travel great distances. Rosenberg wanted to determine how far and where oil might spread.



Drift Card – Ocean Current Study

If recovered, please keep card and report card #, time and location where found to:

www.salishseaspillmap.org

or

email: spillmap@raincoast.or

or

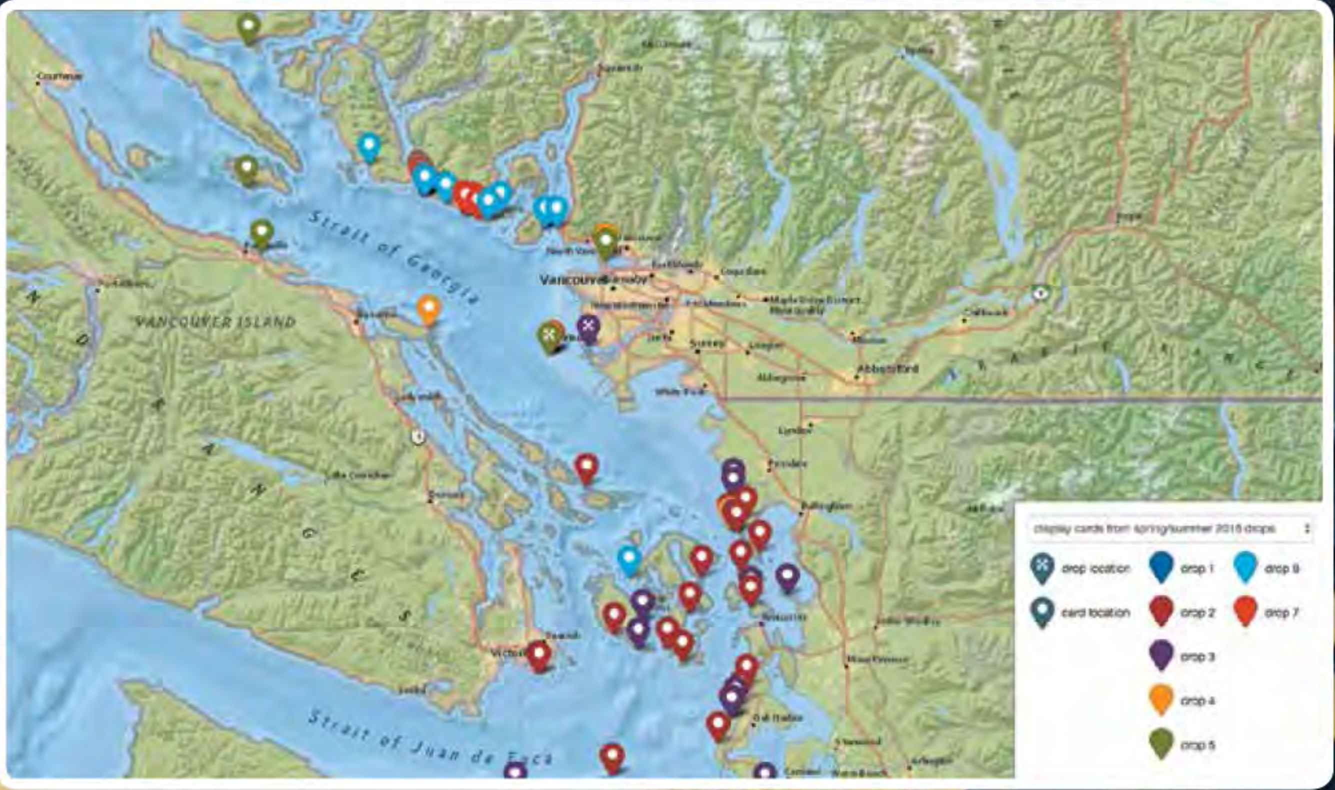
call: 1 (877) 655-1229 x 22.

This project will help to inform our knowledge
ocean currents and potential oil spill trajectories
and will raise awareness regarding oil spills and
marine pollution from shipping in the Salish Sea.

CARD #

1K-71

THIS COULD BE OIL


Strait of Georgia
VANCOUVER ISLAND
Vancouver
Abbotsford
Victoria
Strait of Juan de Fuca
display cards from spring/summer 2016 drops
drop location
card location
drop 1
drop 2
drop 3
drop 4
drop 5
drop 6
drop 7

Getting the Public Involved

Rosenberg created the floating drift cards as stand-ins for the spilled oil. He distributed them at key locations in local waters, in different seasons. Rosenberg also set up a website showing a map of the area, including where he'd dropped the drift cards. He encouraged the public to log on and report the finding of any cards, including their location and the date and time of the recovery. This would assist him in creating maps to show possible results of different spill scenarios.

As of April 2016, members of the public have reported the locations of more than 1800 drift cards—from the Salish Sea all the way up to Alaska. Raincoast Conservation is working to analyze the findings.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. Why did Rosenberg make his drift cards out of plywood? What other kinds of materials are used to make drift cards, and why?
2. Substances in oil can be poisonous. They can cause harm inside the body. They can damage skin or irritate eyes. They can coat fur or feathers.
   - a) How does the density of oil determine what kind of organisms are affected most by oil spills?
   - b) Not all oil being carried in pipelines is alike. Find out how diluted bitumen is different from conventional oil. Compare the effects of a spill of each type.
3. Alexandra Woodsworth campaigns for a B.C.-based environmental group. She believes another benefit of the drift cards is that they engaged the public in a key issue: oil spills.
   - a) Do you think that public involvement in scientific studies is important? Why or why not?
   - b) How could the Internet encourage more public involvement in studies overall?

CONCEPT 2

Matter can be described by its chemical properties.

Activity

What's a Chemical Property?

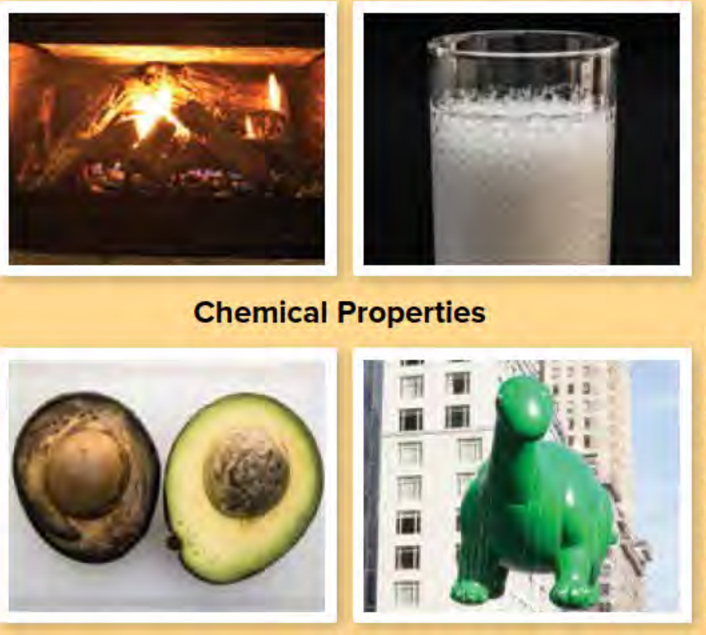
Which of these situations do you think describes a chemical property and why?

- The flesh of an apple turns brown when exposed to air.
- Copper wire can be bent to form a coil.

chemical property ability of matter to react with another substance to form one or more new substances

A **chemical property** describes the ability of matter to react with another substance to form one or more new substances with different properties. Chemical properties can only be observed when a substance chemically interacts, or reacts, with another substance. Some examples of chemical properties are shown in Figure 2.8.

Figure 2.8 Chemical properties are only observed when substances chemically interact to form new substances—or when they fail to do so.



Chemical Properties

Combustibility describes the ability of a material to catch fire and burn in air. We can burn wood and other fuels, such as natural gas and propane, because of their combustibility.

Reactivity with acids is a chemical property. Some substances react vigorously with acids and others do not. Here, a gas forms when baking soda is mixed with vinegar, which is an acid.

Reactivity with oxygen is a chemical property. Substances in foods such as avocadoes, apples, and bananas react with oxygen when exposed to air. Different substances are formed that give the exposed food a brown colour.

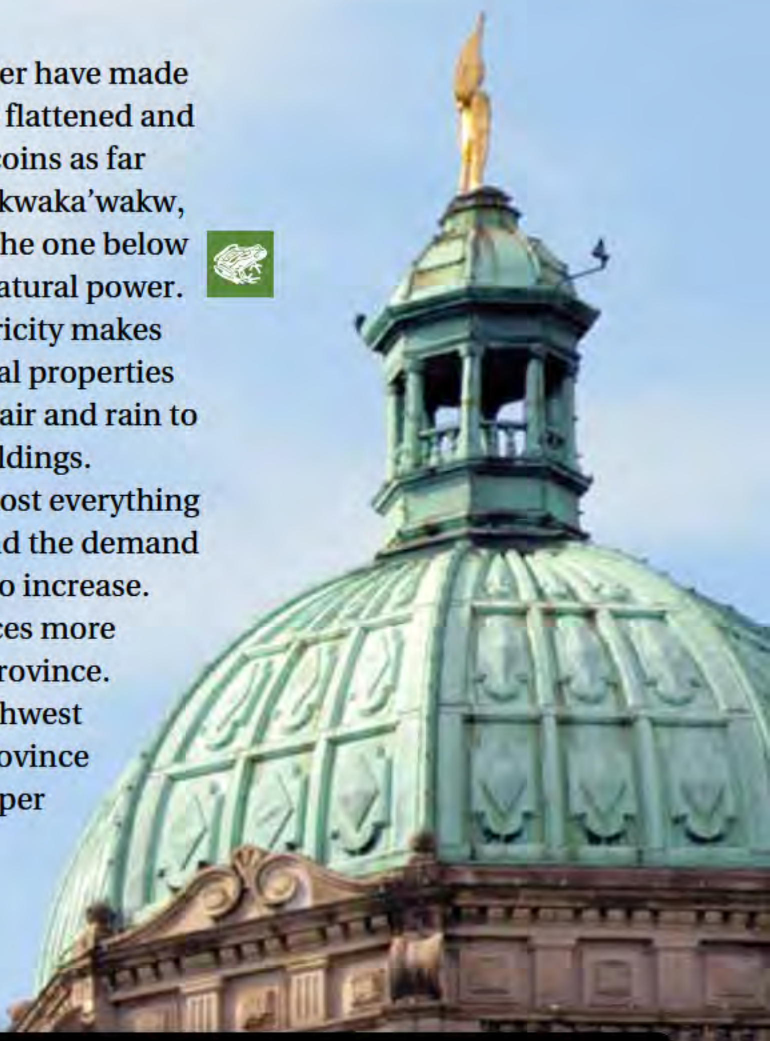
Lack of reactivity is another chemical property. Substances that do not react with other substances are called "inert." Helium, used to fill balloons for parties and parades, is one example of an inert substance.

Before you leave this page . . .

1. What is the main difference between physical and chemical properties?
2. Explain why melting point is not a chemical property.

AT ISSUE

How do we measure the worth of copper?

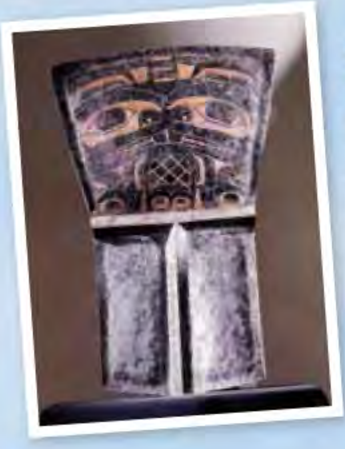


What's the Issue?

The physical and chemical properties of copper have made it valuable throughout history. Copper can be flattened and shaped without breaking. It was first used in coins as far back as 8000 B.C.E. For the Haida, Tlingit, Kwakwaka'wakw, Tsimshian, and Bella Coola, coppers such as the one below signified wealth as well as natural and supernatural power.

Copper's ability to conduct heat and electricity makes it useful in the home and industry. Its chemical properties include the ability to combine with oxygen in air and rain to form a green layer for the B.C. parliament buildings.

Copper is used in almost everything that touches our lives, and the demand for the metal continues to increase. British Columbia produces more copper than any other province. A mine planned for northwest B.C. would make the province home to the largest copper mine in the world.



Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. Research the physical and chemical properties of copper. Also find out the different uses for copper. How do its physical and chemical properties relate to the ways people use copper?
2. Describe the Seabridge Gold Inc. plan to build a combined gold and copper mine in northwest B.C. What approvals did the company need? What controversies have been associated with this project, and why?
3. Copper is mined in B.C. by open-pit mining. What is open-pit mining and what are some concerns that are associated with it? How do mining companies try to reduce the risks? In your opinion, are the benefits worth the risks?

CONCEPT 3

Matter can be described based on physical and chemical changes.

Activity

What Changes Are Happening?

Your teacher will give you and a partner a test tube with water and part of an Alka-Seltzer® tablet. The tablet contains baking soda and citric acid. Make a list of the physical properties of the water and tablet. Predict what will happen when the tablet is added to the water. Add the tablet to the water and observe what happens. Which changes do you think are physical changes? Which are chemical changes? Explain.

Physical Changes

physical change change of matter that does not alter its chemical identity or composition

A **physical change** is a change that alters a substance without changing its chemical identity or composition. Crumpling a sheet of aluminum foil into a ball or folding a piece of paper into the shape of a bird are examples of physical changes. The crumpled ball of foil is still aluminum and the folded paper is still paper. Figure 2.9 shows a familiar physical change.

The freezing of water to form ice is also an example of a physical change—the frozen, solid water is still water. Substances can exist in gas, liquid, or solid forms. These forms are called states. For example, you are most familiar with gold in its solid state. But gold can exist as a liquid or even a gas. However, extreme conditions are needed to change gold into its gas state, because its boiling point is 2856°C, which is hotter than most furnaces can get.

When a substance changes from one state to another, the physical change is known as a *change of state*.

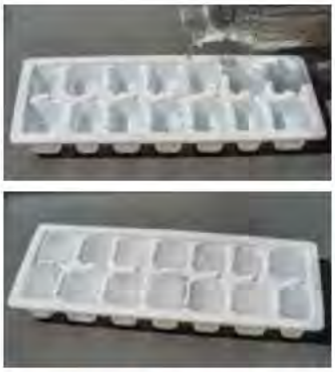


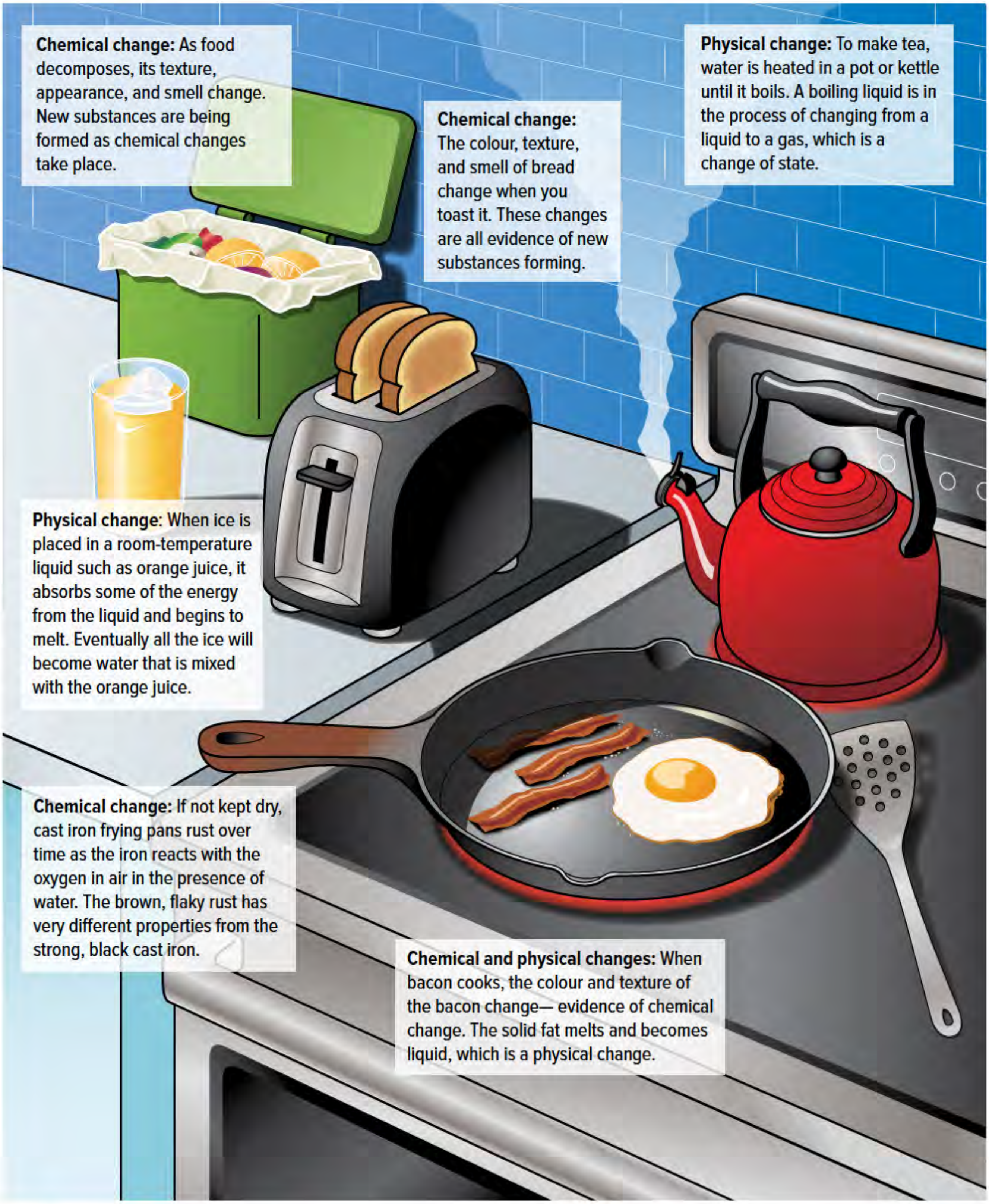
Figure 2.9 Freezing is a physical change.

Chemical Changes

chemical change change of matter that produces new substances

During a **chemical change**, or *chemical reaction*, one type of matter changes to produce one or more different types of matter. The matter that is produced has a different identity and different properties from the original matter. The substances that take part in a chemical change are called the *reactants*. The substances that are formed by the chemical change are called the *products*. Figure 2.10 shows some physical and chemical changes involved in preparing food.

Connect to Investigation 2-C on pages 126–127



Chemical change: As food decomposes, its texture, appearance, and smell change. New substances are being formed as chemical changes take place.

Chemical change: The colour, texture, and smell of bread change when you toast it. These changes are all evidence of new substances forming.

Physical change: To make tea, water is heated in a pot or kettle until it boils. A boiling liquid is in the process of changing from a liquid to a gas, which is a change of state.

Physical change: When ice is placed in a room-temperature liquid such as orange juice, it absorbs some of the energy from the liquid and begins to melt. Eventually all the ice will become water that is mixed with the orange juice.

Chemical change: If not kept dry, cast iron frying pans rust over time as the iron reacts with the oxygen in air in the presence of water. The brown, flaky rust has very different properties from the strong, black cast iron.

Chemical and physical changes: When bacon cooks, the colour and texture of the bacon change— evidence of chemical change. The solid fat melts and becomes liquid, which is a physical change.

Figure 2.10 Even a simple task like preparing a meal involves many physical and chemical changes. **What are some other chemical or physical changes that take place in a kitchen? List one of each not shown in the illustration.**

Law of Conservation of Mass

Early scientists experimented with chemical changes by heating, burning, and mixing matter. These studies included measuring the masses of substances before and after chemical changes had occurred.

French scientist Antoine Lavoisier (1743–1794) and his wife Marie-Anne carried out many chemical reactions, measuring the mass of substances before (the *reactants*) and after (the *products*). **Figure 2.11** shows an example of one of these experiments. Over and over again, the Lavoisiers observed that mass did not change when a chemical reaction took place. The mass of the reactants was always equal to the mass of the products. This observation was summarized as the *law of conservation of mass*. According to this scientific law, mass is neither created nor destroyed during a chemical reaction—it is conserved.

Connect to Investigation 2-D on pages 128–129

The Law of Conservation of Mass

mass of reactants = mass of products

In any chemical reaction, the total mass of the products is the same as the total mass of the reactants.

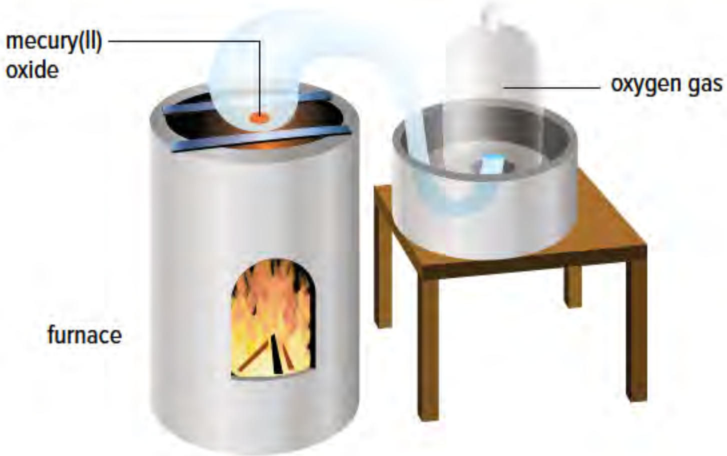


Figure 2.11 Lavoisier sealed a powdery, red-coloured chemical called mercury(II) oxide in a container. After intense heating, the red powder was changed to silvery liquid mercury and oxygen gas. The mass after the reaction was the same as the mass before the reaction.

Before you leave this page . . .

1. What is the main difference between a physical change and a chemical change?
2. State the law of conservation of mass in your own words.
3. In Lavoisier's experiments, why was it important that the container be sealed? Explain your answer.

AT ISSUE

How does B.C. snowmaking compare with other parts of the world?

What's the Issue?

B.C. is a paradise for skiers and snowboarders, with its huge mountains and wide spaces. But the ski and snowboard industries are important for more than the fun that they provide. They employ about 14 000 people, account for 8 percent of the province's total tourism revenues year-round, and bring in more tourism dollars than any other sector in the winter.

However, snowfall is unpredictable and varies from year to year. In the winter of 2014, El Niño brought warmer temperatures to the west coast, and this brought more rain than snow to the hills. Fourteen percent fewer skiers visited B.C. ski resorts that year. There is also the threat of climate change reducing annual snowfalls.

Owners of many ski resorts in British Columbia and around the world have invested millions of dollars to purchase snowmaking machines so they can make their own snow. By using snowmakers, resorts can ensure ski runs have lots of snow throughout the season. The resorts can also extend the ski season beyond what would be possible if they relied on natural snowfall alone. During the 2010 Winter Olympics, held in Vancouver, snowmakers were essential to ensuring events could run as planned. The benefits are clear, but are there financial and environmental costs associated with snowmaking?

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. How does snow form naturally? Describe the process in four or five steps. Then find out about the process of snowmaking. Describe one system of snowmaking in four or five steps. Compare the two processes, including the amount of energy each requires. Why is it important to do this comparison?
2. How are the crystals that snow machines make different from natural snow crystals? Explain whether you would call them "artificial snow" or not.
3. Where do ski resorts in Canada get the water they use for making snow? How does this compare with other parts of the world? What are possible effects on the local and global environment of using these sources of water for making snow?

CONCEPT 4

Matter can be classified based on how it responds to physical and chemical changes.

Connect to Investigation 2-E on pages 130–131

Matter can be classified based on how it can be separated or broken down using physical and chemical changes. As you can see in Table 2.1, matter can be either a mixture or a pure substance. A pure substance can be either a compound or an element. The rest of the unit will focus on pure substances and the models and theories that help explain their properties and changes.

Table 2.1 Classifying Matter Based on Physical and Chemical Changes

Type of Matter	Description	Examples	
Mixtures	Can be separated into parts by physical changes.	A mixture of iron filings and sand can be separated using a magnet.	A solution of salt and water can be separated by allowing the water to evaporate.
Pure substances	Compounds: Can be broken down into two or more elements by chemical changes but not physical changes.	Passing an electric current through water produces the elements hydrogen and oxygen.	
	Elements: Cannot be separated or broken down by physical or chemical changes.	These lights contain neon gas, an element.	

Before you leave this page . . .

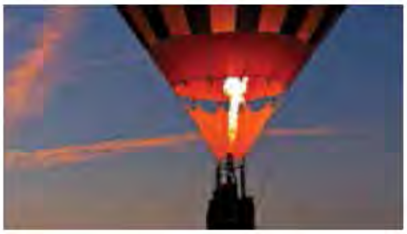
1. Classify each of the following as a mixture or a pure substance.
   a) oxygen b) lemonade c) mercury(II) oxide

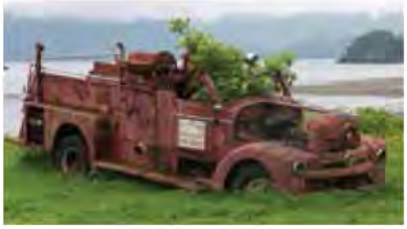
Check Your Understanding of **Topic 2.2**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Define volume and give two examples of units used to express it. PA C
2. Define mass and give two examples of units used to express it. PA C
3. Explain how density is related to mass and volume. PA C
4. For each image below, give a physical property and a chemical property that is shown in the image. Describe each property. PA

a)


b)


5. Read the three descriptions below. Which is a physical change? Which is a chemical change? Explain your answers.
   - **a)** Salt can be extracted from salt water by heating it. The water evaporates into the air and the salt stays behind.
   - **b)** Many cake recipes include baking powder because, when it mixes with water, it produces carbon dioxide gas that helps batter to rise.
   - **c)** When you bend a light stick, the materials inside it are allowed to mix, and light is given off. PA E
6. Iron pyrite is commonly called fool's gold because of its golden colour. Suppose you found a golden solid that has a mass of 25.04 g and a volume of 4.99 cm^3. Use the data in the table below to determine if you have found iron pyrite or gold. QP PA E

Material	Density g/cm^3
gold	19.3
iron pyrite	5.02

Connecting Ideas

7. A student argues that a sample of sugar water is a pure substance because it contains only sugar and water, nothing else. Do you agree with this classification? Why or why not? How would you respond to this argument? C QP

Making New Connections

8. Many First Peoples of British Columbia, as well as throughout North America, are expert canoe-makers.
   - **a)** What understandings about properties and changes of matter do you think First Peoples developed to perfect the science and art of canoe-making?
   - **b)** How is the making of canoes connected with the spiritual/cultural life of First Peoples? QP PA E AI
9. The law of conservation of mass is more than 200 years old. It is still accepted by scientists today. How can they be so confident about it? Use scientific understanding to explain your reasoning. AI PA

INVESTIGATION

2-C

GUIDED INQUIRY

Testing Physical and Chemical Properties of Matter

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

Safety

What You Need

- samples of matter to test (e.g., paper, cork, baking soda, copper, aluminum strips, table salt, sugar, carbon [graphite], cooking oil)
- water
- dilute acid
- test tubes
- test tube rack
- marker

In this investigation, you will develop your own questions that will guide your study of the properties of matter.

Procedure

1. Your teacher will give you two samples of matter to study. Write out any questions you have about the properties of these samples.
2. Decide which questions you will investigate. Make predictions about the answers to your questions.
3. Plan a procedure that you will follow to answer your questions. A description of how to perform different tests is provided in the table on the opposite page.

   You can use the questions below to help guide your procedure:

   - What physical and chemical properties will I investigate?
   - How will I record and organize the observations I make? For properties that need to be rated, how will I do it? For example, how do I rate the lustre of a substance?
   - What procedure will I need to follow to study a particular property?
4. Have your teacher approve your procedure.
5. Carry out your plan once your teacher has approved it.
6. Dispose of any chemicals according to your teacher's instructions.

Evaluate

1. Did you determine the answers to your questions? If so, what are they? If not, why were you not able to? What other evidence would you need to answer your questions?

2. Share your results with your teacher, who will record them in a class chart. Reflect on the properties for all the substances that were studied.
   - Look for patterns you can use to group the substances according to common physical or chemical properties.
   - What groupings of substances can you make? Explain what these groupings are based on.

Apply and Innovate

3. Think about how each substance you studied is used. How do you think the physical and/or chemical properties of each substance are related to its function?

Tests for Properties

Properties	Test
Physical Properties	
colour, state, lustre	Describe the appearance.
malleability	Try to bend the solid material.
density	Calculate based on mass and volume.
texture	Feel the surface.
odour	**Never inhale directly.** Waft the air above the sample toward you and very gently inhale.
solubility in water	**1.** Place 1 mL of water in a test tube. **2.** Place a small amount of the sample being tested in the water. **3.** Gently tap the bottom of the tubes with your finger while holding the tube in the other hand. **4.** Look to see if all, part, or none of the sample dissolves.
Chemical Properties	
reactivity with water	**1.** Place 1 mL of water in a test tube. **2.** Place a small amount of the sample being tested in the water. **3.** Gently tap the bottom of the tube with your finger to mix the contents. **4.** Look for evidence of one or more new substances forming.
reactivity with acid	**1.** Place 1 mL of dilute acid in a test tube. **2.** Place a small amount of the sample being tested in the test tube. **3.** Look for evidence of one or more new substances forming.

INVESTIGATION
2-D

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

Safety

What You Need

- 1 mL measuring scoop
- test tubes and stoppers
- test tube rack
- resealable plastic bag
- beakers
- water
- ice
- matches
- sand
- baking soda
- citric acid
- table salt
- 0.1 mol/L potassium iodide
- 0.1 mol/L lead(II) nitrate
- vinegar

Physical and Chemical Changes

In this investigation, you will observe the results of physical and chemical changes.

Question

What observations help to determine if a chemical or physical change has occurred?

Procedure

1. The procedures you will carry out are described in the table on the opposite page. Read them and predict what you think will happen in each case.
2. Design a table with headings like the ones below to record your observations.

Station Number	Procedure Summary	Observations			Type of Change
		Before	During	After	

3. Begin at the station assigned by your teacher. Move to the next station when directed by your teacher.
4. Each station has instructions for the procedure and how to dispose of the materials. Be sure to follow these instructions.
5. Wash your hands as soon as you have finished the investigation.

Process and Analyze

1. What physical changes did you observe? For each one, describe the observations that provide evidence of a physical change.
2. What chemical changes did you observe? For each one, describe the observations that provide evidence of a chemical change.
3. How did your predictions compare with your observations?

Evaluate and Communicate

4. Which changes were difficult to classify, and why? What further tests would have helped?
5. Summarize the types of evidence that someone can use to identify physical changes and chemical changes.
6. One of the substances in the materials list for this Investigation has lead in it. Your teacher may have used a different chemical instead of this one. Do research to find out why lead is a particular concern, and why disposing of it must be done in a special manner.

Chemical and Physical Changes

Station	Procedure
Station 1: baking soda and citric acid	• Place a 1 mL scoop of baking soda into one corner of a resealable plastic bag. • Add 1 mL scoop of citric acid in the same corner of the bag. Observe the bag for changes. • Twist the corner of the bag so that the solid chemicals are isolated. Add 3 mL of water in the other corner of the bag. Press the air out of the bag and seal the bag. • Untwist the corner of the bag and mix the contents.
Station 2: salt water	• Fill the bottom of a test tube with salt. • Add water to about one-third of the test tube, stopper the tube, and gently shake.
Station 3: ice	• Put 2 or 3 small pieces of ice into a 100 mL beaker, and cup the beaker in the palm of your hand.
Station 4: matches	• Strike a match and watch as it burns.
Station 5: potassium iodide and lead(II) nitrate	• Add 5 drops of potassium iodide solution into a test tube. • Add 5 drops of lead(II) nitrate solution **Due to the presence of a lead compound, it is very important for your teacher to follow the disposal instructions when you are done.**
Station 6: water and sand	• Add about 1 mL of water to a test tube. • Add a scoop of sand to the test tube, stopper the tube, and gently shake.
Station 7: water and vinegar	• Add about 1 mL of water to a test tube. • Add about 1 mL of vinegar to the test tube, stopper the tube, and gently shake.

INVESTIGATION
2-E

STRUCTURED INQUIRY

Separating a Mixture by Paper Chromatography

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

Safety

What You Need

- 400 mL beaker
- filter paper with ink dot about 1.5 cm from end
- water
- plastic straw
- tape
- paper towel

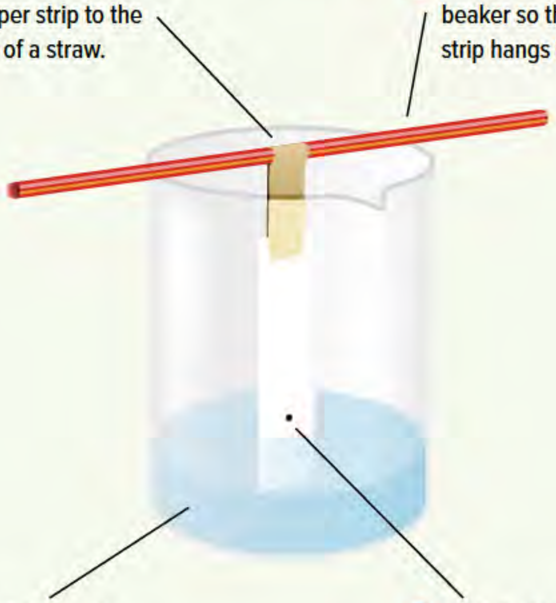
If you want to know what is in a mixture, there are a variety of ways to separate and identify its component substances by using their different properties. In this Investigation, you will separate a mixture of ink using a method called paper chromatography.

Question

How can you separate the components of ink?

Procedure

1. Set up a beaker as shown below.



B Tape the clean end of the paper strip to the centre of a straw.

C Rest the straw across the beaker so the bottom of the strip hangs in the water.

A Add about 1 cm of water to the beaker.

D The ink dot should be a few millimetres above the water level.

2. Leave the beaker undisturbed until the ink has moved a few centimetres up the strip and you can clearly detect some separation of the ink into more than one colour. Then remove the strip and let it dry on some paper towel.
3. Clean up your work area and dispose of waste as instructed by your teacher.

Process and Analyze

1. Sketch and describe what you observed on the paper strip.
2. How many different colours can you see? How do you explain what you see?

Communicate and Apply

3. How do the physical properties of the different substances in the ink relate to this method of separating a mixture?
4. Predict what would happen if you repeated this Investigation using permanent ink.
5. Find out more about the technique of chromatography.
   a) In addition to paper chromatography, what other types of chromatography are there? How do these types of chromatography work?
   b) What kinds of jobs make use of chromatography?
   c) How is chromatography used in each of the following applications?
      - forensics
      - analysis of food and drink
      - drug testing
      - airport security

Gas chromatography is an important tool used to separate mixtures and identify the substances in them.

TOPIC 2.3

How can we describe and explain the states of matter?

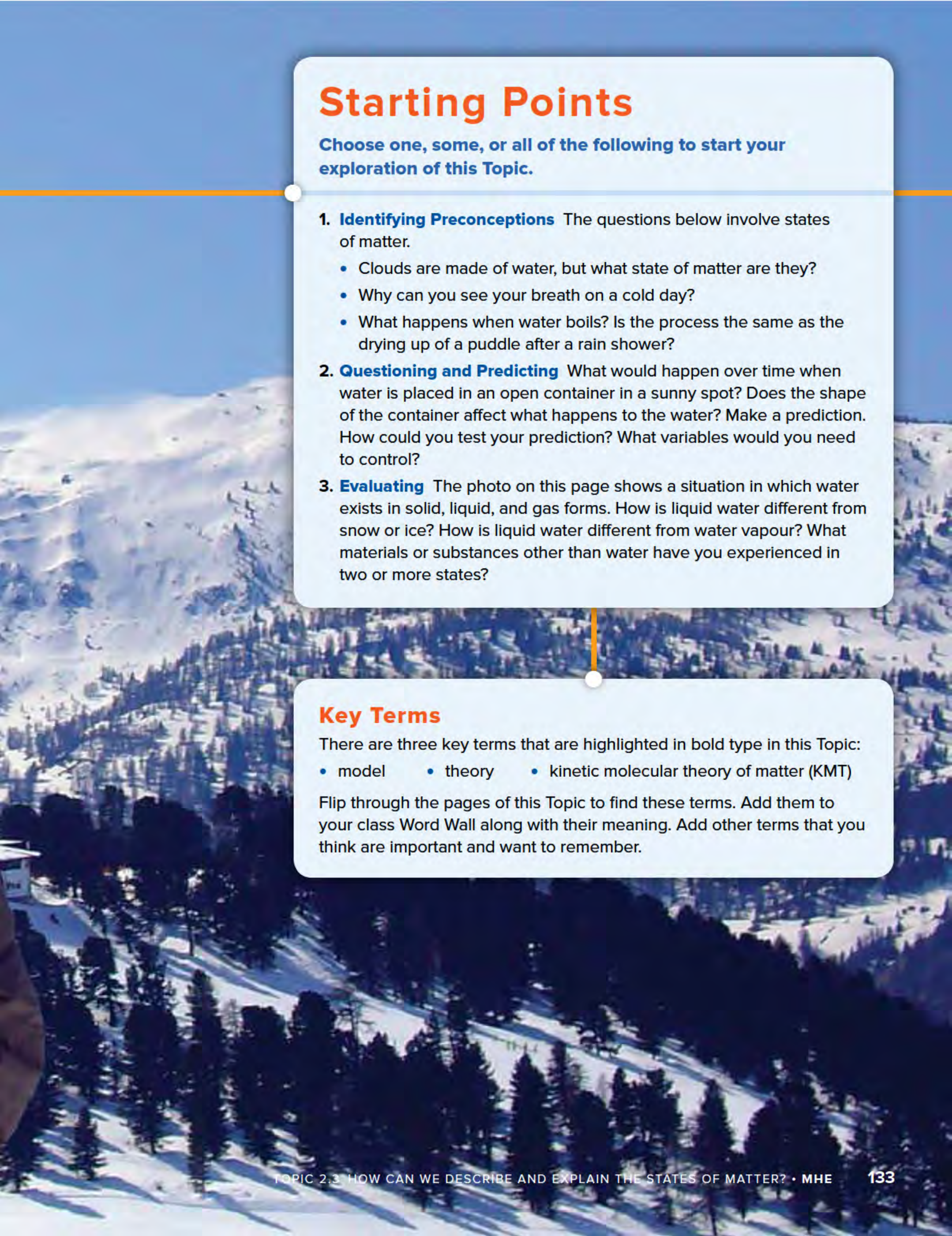
A skier pauses to take a drink of spring water, and then he breathes deeply. When he exhales, he will see small white puffs forming, similar to the clouds drifting above. Soon he will grab his poles and race down the hill, gliding along and carving into the snow and ice. The skier is experiencing water in all its forms: as a drinkable liquid, as a skiable solid, and as an invisible gas that he breathes in and out as part of the mixture we call air. Why does water in its different states—solid, liquid, and gas—have such different properties?

Key Concepts

- Matter can be solid, liquid, or gas.
- Matter is made of particles in constant motion.
- Changes in state result from changes in particle motion.
- The kinetic molecular theory explains physical changes and properties.

Curricular Competencies

- Make observations aimed at identifying your own questions about the natural world.
- Use scientific understandings to identify relationships and draw conclusions.
- Demonstrate an awareness of assumptions and identify bias in your own work and secondary sources.
- Communicate ideas using scientific language and representations.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The questions below involve states of matter.
   - Clouds are made of water, but what state of matter are they?
   - Why can you see your breath on a cold day?
   - What happens when water boils? Is the process the same as the drying up of a puddle after a rain shower?
2. **Questioning and Predicting** What would happen over time when water is placed in an open container in a sunny spot? Does the shape of the container affect what happens to the water? Make a prediction. How could you test your prediction? What variables would you need to control?
3. **Evaluating** The photo on this page shows a situation in which water exists in solid, liquid, and gas forms. How is liquid water different from snow or ice? How is liquid water different from water vapour? What materials or substances other than water have you experienced in two or more states?

Key Terms

There are three key terms that are highlighted in bold type in this Topic:

- model
- theory
- kinetic molecular theory of matter (KMT)

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Matter can be solid, liquid, or gas.

Activity

What Is It?

Working in groups, add 250 mL of cornstarch into a large bowl. Feel the cornstarch with your hand. Then slowly add 85 mL of water and mix the cornstarch as you add the water. Mix the cornstarch with your hands so that you can feel the texture and consistency. Add some food colouring if you wish. Then experiment with the mixture. What happens when you grab a handful of the mixture and try to form a ball with it? Now open up your hand. What happens to the ball? Slap the cornstarch mixture quickly. Now try squeezing it. Is it a liquid? Is it a solid? How do you know?

Matter can exist as a solid, liquid, or gas. What are some examples of liquids and solids in your everyday life? Just this morning, you may have taken a shower in water and used some shampoo and conditioner on your hair: that's three liquids. Perhaps you had a glass of juice or poured some milk on some cereal in a bowl and ate it with a metal spoon. That's two more liquids and four solids. It can be hard to think of gases as matter because many gases are invisible. Although you cannot see them, gases surround us—you can feel gases filling your lungs every time you take a breath. **Figure 2.12** describes examples of solids, liquids, and gases.

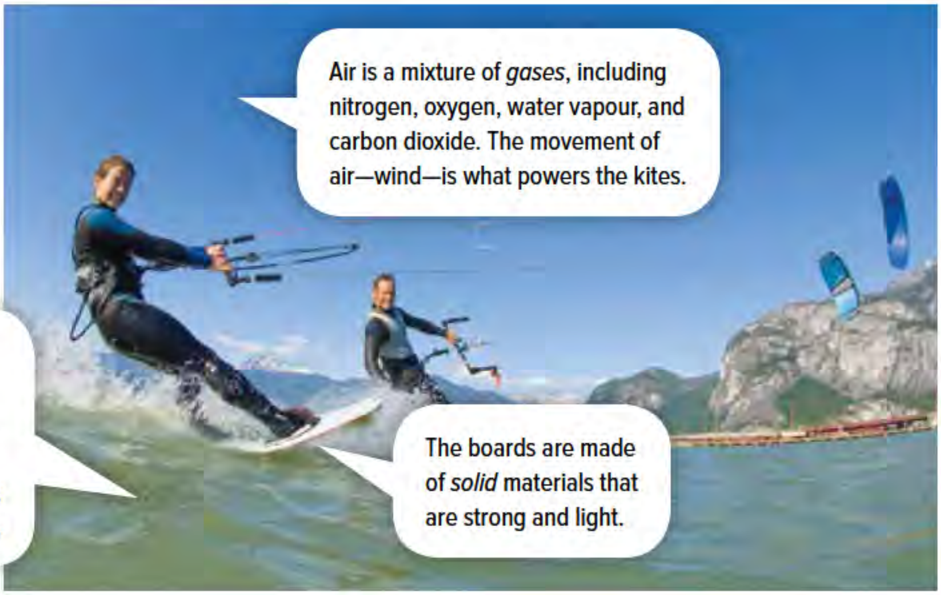


Figure 2.12 Kiteboarders depend on the different properties of solids, liquids, and gases to enjoy their sport. **List three solids shown but not mentioned here and describe their physical properties.**

Air is a mixture of *gases*, including nitrogen, oxygen, water vapour, and carbon dioxide. The movement of air—wind—is what powers the kites.

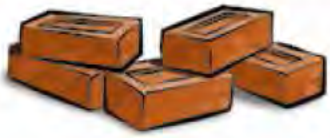
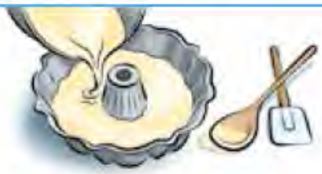
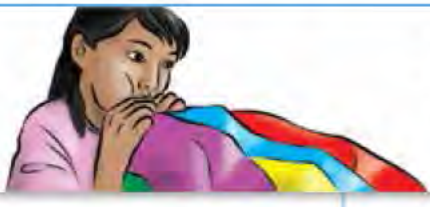
Ocean water is a *liquid* mixture of water and dissolved salts. It also contains suspended solids such as grains of sand. Kiteboarders can skim along the surface of the water, or sink into it safely if the wind fails.

The boards are made of *solid* materials that are strong and light.

Properties of the States of Matter

Solids, liquids, and gases have distinct characteristics that can be used to classify them. These characteristics are summarized below in Table 2.2.

Table 2.2 States of Matter

State	Common Characteristics	Examples
solid	• holds its own shape • has a constant volume	 • wood • silver • stone • plastic
liquid	• takes the shape of its container • has a constant volume	 • oil • juice • antifreeze • gasoline
gas	• takes the shape and volume of its container • can be compressed	 • air • helium • hydrogen

The Fourth State

Solids, liquids, and gases are the most familiar states of matter. But most matter in the universe actually exists as a fourth state of matter called plasma. A plasma is similar to a gas in that it does not have a defined shape and volume, but plasmas have different electrical properties than gases. Some examples of plasmas are shown in Figure 2.13.

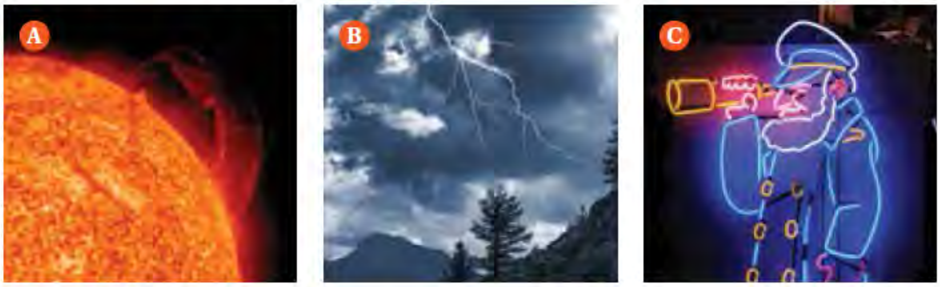


Figure 2.13 The fourth state of matter, plasma, is found on Earth and throughout the universe. Ⓐ All stars, including our Sun, are made up of plasma. Ⓑ The visible fork of a lightning bolt is plasma formed in the air by an electrical current. Ⓒ The glowing gas of a neon sign is actually plasma.

Before you leave this page . . .

1. Give two examples of solids, liquids, and gases.
2. Which state of matter does plasma most resemble and why?

CONCEPT 2

Matter is made of particles in constant motion.

Activity

Musing on Models

What does the term “model” mean to you? Write a brief definition. What are some different examples of models in everyday life? How do you think models are used in science?

model a verbal, mathematical, or visual representation of a scientific structure or process

theory a scientific explanation that has been supported by consistent, repeated experimental results and is therefore accepted by most scientists

The terms “model” and “theory” have a variety of different meanings in different contexts. In science, however, they have very specific meanings.

A **model** consists of words, pictures, physical objects, or mathematical equations that are used to represent and explain complex objects, living things, or events in nature. Models help people analyze and communicate what they observe in the natural world. They also help us visualize processes that cannot be seen with the unaided eye. Some examples of models are shown in **Figure 2.14.**

A scientific **theory** is an explanation of a phenomenon in the natural world based on many observations and investigations. Theories can be, and often are, modified or discarded if new experimental data arise that contradict the theory or that the

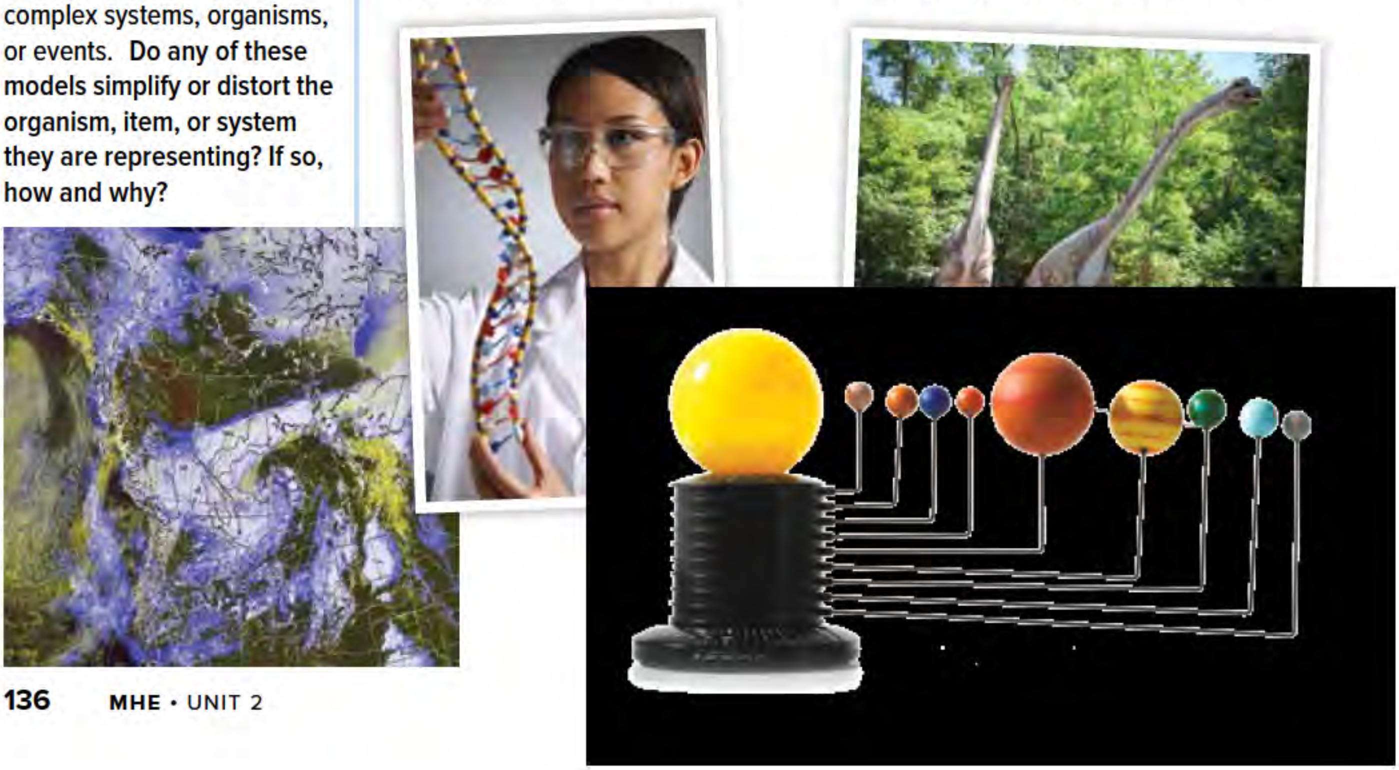


Figure 2.14 These models were made to help people understand or analyze complex systems, organisms, or events. **Do any of these models simplify or distort the organism, item, or system they are representing? If so, how and why?**

theory cannot explain. Theories often lead to new conclusions. A theory is considered successful if it both explains experimental observations and can be used to make accurate predictions. A theory is never considered to be proven, no matter how successful it is. Future experiments may lead to further changes.

Explaining Properties of the States of Matter

The *particle model of matter* is a model that enables people to visualize and understand the structure of matter, even though we cannot see it. According to the particle model of matter, all matter is made up of very small particles. These particles are so small that they cannot be seen even with the help of a light microscope.

Using the particle model of matter, scientists developed a theory to explain the behaviour of gases. This scientific theory, when extended to explain the behaviour of all states of matter, is called the **kinetic molecular theory of matter (KMT)**. An important part of the kinetic molecular theory of matter is the notion of *kinetic energy*—the energy of motion. According to the theory, all particles are constantly moving and therefore have kinetic energy. The kinetic molecular theory successfully explains many observations about matter, including the different properties of the states of matter, as well as the ways in which matter changes state.

kinetic molecular theory of matter (KMT) a scientific explanation of the behaviour of matter based on all matter being made of particles that possess kinetic energy

The Kinetic Molecular Theory of Matter

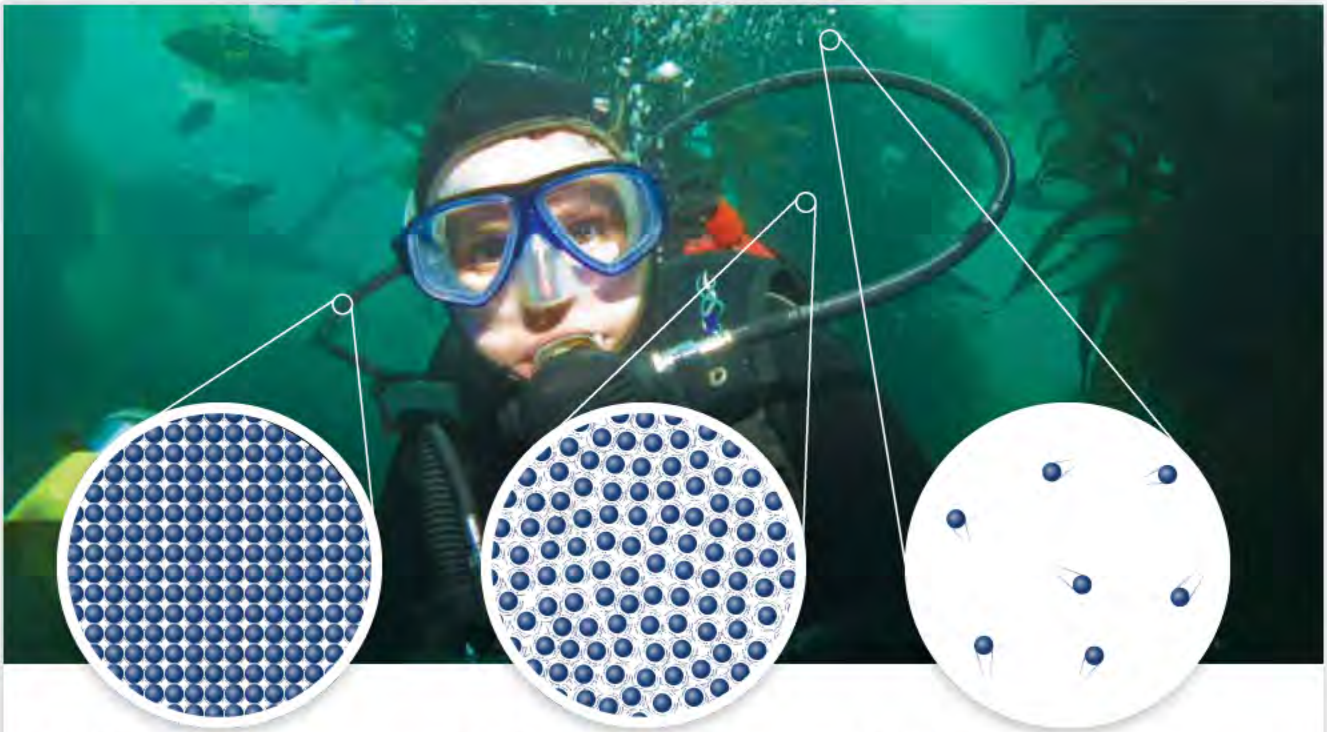
The key points of the kinetic molecular theory of matter are:

1. All matter is made up of very small particles.
2. The particles exist in empty space.
   - **(a)** In solids, particles are closely packed and held rigidly in place.
   - **(b)** In liquids, particles are also closely packed but can move around.
   - **(c)** In gases, particles have large amounts of empty space between them and are not attracted to one another.
3. Particles are constantly moving.
   - **(a)** The particles in solids vibrate but cannot move around.
   - **(b)** The particles in liquids slip and slide past and revolve around each other but stay close together. They collide with each other and the walls of their container.
   - **(c)** The particles in gases move freely in straight lines, colliding with each other and with the walls of their container.
4. Energy makes particles move. The more energy the particles have, the faster they can move and the farther apart they can get.

States of Matter and the Kinetic Molecular Theory

To use the kinetic molecular theory as a tool for explaining observations about the states of matter, it can help to visualize the particles for each state, as shown in **Figure 2.15**. Note that the particles in a gas are actually much farther apart than is suggested by the diagram.

Figure 2.15 The kinetic molecular theory explains the properties of solids, liquids, and gases based on how their particles are arranged and how they move.



Particles in a Solid
- very close together
- vibrate but do not move around
- attract one another strongly in a rigid structure

Particles in a Liquid
- very close together
- slip and slide past and revolve around one another
- attract one another less strongly than in solids

Particles in a Gas
- very far apart compared to their size
- move randomly and quickly in straight lines
- attraction to one another is effectively zero

Before you leave this page . . .

1. In what ways does a model differ from a theory?
2. Summarize the kinetic molecular theory of matter.
3. Describe the particles of the three states of matter in terms of how they move and the spaces between them.
4. It is easy to compress (reduce the volume of) a gas, but solids and liquids cannot be compressed very much. Use the KMT to explain why.

CONCEPT 3

Changes in state result from changes in particle motion.

Activity

The Cold Can

Dry the outside of a metal can with paper towel. Obtain 50 g (about 45 mL) of salt. Divide it into three approximately equal portions. Add the first portion of salt to the can, then half-fill the can with crushed ice. Add the second portion of salt and fill the can with ice. Top with the rest of the salt. Mix the contents well, being careful not to spill the contents of the can. Wait 5 minutes and observe the outside and inside of the can. How do you explain what you observe?

Changes of state (also referred to as phase changes) occur when matter transforms from one state to another. Most pure substances can exist in all three states depending on the temperature and pressure. A few substances, such as water, exist in all three states under ordinary conditions on Earth. Scientists use specific terms to refer to the different state changes that are possible among solids, liquids, and gases, as shown in Figure 2.16.

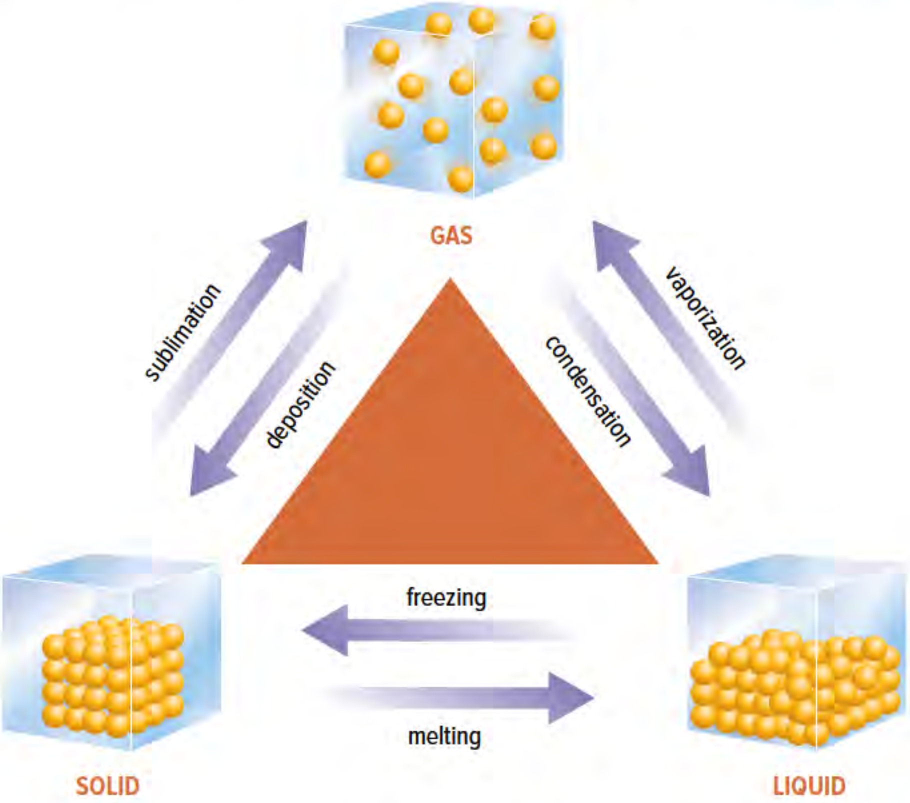


Figure 2.16 Specific terms such as melting and evaporation are used to describe how the state of matter can change.

Changes of State and Temperature

What causes matter to change from one state to another? Consider what is the same about the following examples. You put a scoop of solid butter in a hot frying pan and it melts into a liquid. A kettle full of water begins to "sing" as the heating element inside causes the water to boil. You drop some ice cubes into your orange juice and they begin to melt. You fill the empty ice cube tray with water and pop it in the freezer to make more ice. All of these examples involve adding or removing kinetic energy.

Adding energy to matter or removing energy from matter changes the temperature of the matter. What does that mean? *Temperature* is a measure of the average kinetic energy of the particles in a substance. Increasing the temperature of matter means the particles of the matter are gaining energy. Once the matter reaches a certain temperature, the particles have gained enough energy to change state.

The temperature at which a substance melts is called its *melting point*. The temperature at which a substance boils is called its *boiling point*. The melting and boiling points of pure substances are physical properties that can be used to identify them. A few examples are shown in Table 2.3.

Table 2.3 **Melting and Boiling Points**

Substance	Melting Point (°C)	Boiling Point (°C)
nitrogen, N_2	–210.0	–195.8
mercury, Hg	–38.8	356.7
water, H_2O	0.00	100.0
iron, Fe	1538	2862

The Kinetic Molecular Theory and Changes of State

The difference between the properties of solids, liquids, and gases can be explained by the difference in the kinetic energy of the particles of substances in those states. For any given substance, the average kinetic energy of the particles in the solid will be lower than that of the particles in the liquid. The particles in the gas will have the greatest average kinetic energy.

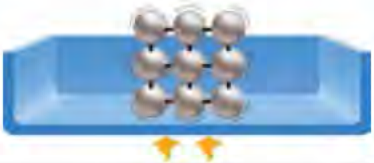
But why do substances change from one state to another when they are heated or cooled? Why does a heated solid melt instead of just becoming a very hot solid? Figure 2.17 shows how the KMT explains changes of state.

Connect to Investigation 2-F on pages 148–149

Adding Energy to Mercury

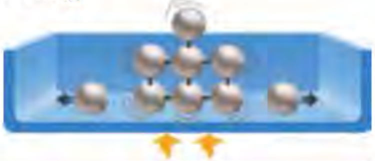
1. Solid mercury

Particles are very close to one another, are fixed in position, and vibrate. They strongly attract one another.



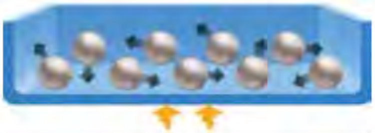
2. Melting mercury

As the temperature of the solid mercury increases, the kinetic energy of the particles increases. Eventually, the increased kinetic energy of the particles allows them to partially overcome their attraction to one another, and they break free of their rigid formation. They now begin to revolve around and slide past one another. The solid is melting.



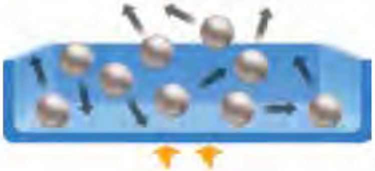
3. Liquid mercury

The particles move freely around one another, but are still close together and strongly attracted. They have taken the shape of their container.



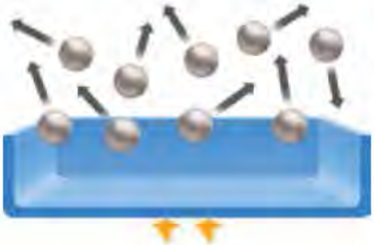
4. Boiling mercury

As the temperature continues to increase, the kinetic energy increases and the particles move more vigorously. Some particles gain enough energy to completely overcome the attractive forces between them and other particles in the liquid. They escape into the surrounding air.



5. Gaseous mercury

All particles are highly energetic and move freely to fill their container. Further heating will increase the speed of the gas particles, which increases their kinetic energy. If in a sealed container, particles will collide with each other and with the walls of the container more forcefully and more often. This increases the pressure of the gas.



Extending the Connections

Applying Deposition

The metallic colours of modern electronics such as phones are due to specialized materials applied using physical vapour deposition (PVD). Research PVD and choose one specific application to explore.

This piece of solid mercury was formed by cooling it to below –38.8°C, the melting point of mercury.

Mercury is the only metal that is a liquid at room temperature.

Figure 2.17 As a sample of solid mercury absorbs energy (shown by the orange arrows), it undergoes two changes of state.

Before you leave this page . . .

1. Define temperature.
2. What is the melting point of a substance?
3. Use the KMT to explain how a liquid changes into a solid.

AT ISSUE What are the dangers of using mercury?

What's the Issue?

Hard-rock gold mining produces most of the world's gold. Because the gold is encased in rock, known as ore, miners must dig out large quantities of ore and then extract the gold from the rock. Some processing companies use mercury to help with this. During the extraction process, workers add liquid mercury to the ore. It forms an amalgam—a mercury-containing mixture—with the gold and helps to separate the gold from the rock.

Although this process is effective, the use of mercury in mining is banned in Canada. Why? Mercury can be highly toxic to people and the environment. For example, in order to remove the mercury from the gold-mercury amalgam, workers heat it, turning the mercury into a vapour. However this process can put workers at risk of breathing in the mercury. Also, the mercury can settle on their clothing and workers can inadvertently transport it into their homes and community, putting others at risk.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Find examples of small- or large-scale mercury contamination. Describe why and how they occurred. Do you think similar events could occur now? Explain why or why not. What properties of mercury make it so hazardous?
2. Research to find past and current applications of mercury. For past applications, find out why mercury is no longer used and what is used instead.
3. Despite its dangers, small-scale mining operations in developing countries continue to use mercury in the gold extraction process. Why do you think this might be? Discuss whether this is an equity issue and whether all countries have a responsibility to find and promote solutions. Research tools miners could use to help protect themselves from mercury poisoning during the extraction process, and explain how they work.
4. Low levels of mercury may not cause problems for animals or the environment, but mercury builds up over time—and high concentrations are toxic. Find out why mercury "builds up over time." Why does this adversely affect the environment?

CONCEPT 4

The kinetic molecular theory explains physical changes and properties.

Activity

Dye-ing to Dissolve

Work in groups. Your teacher will give you two dye tablets of the same colour. Fill one beaker with 250 mL of cold tap water and a second beaker with 250 mL of hot tap water. Place one tablet in each beaker. Record your observations using words and diagrams or photos. Do not stir the mixtures. In your group, come up with a way of communicating your findings. Share and discuss your results as a class.

The kinetic molecular theory explains states of matter and changes of state, but it can also be used to explain other physical changes as well as physical properties. For example, think about what happens when a solid dissolves in a liquid. If you place a sugar cube in water, it will appear to get smaller and smaller as time passes. Soon it will seem to disappear. If you tasted the water, however, it would taste sweet. This is evidence that the sugar has not disappeared but is still present in the liquid. A solution of water and sugar has formed. As shown in Figure 2.18, the kinetic molecular theory can help explain what happened.

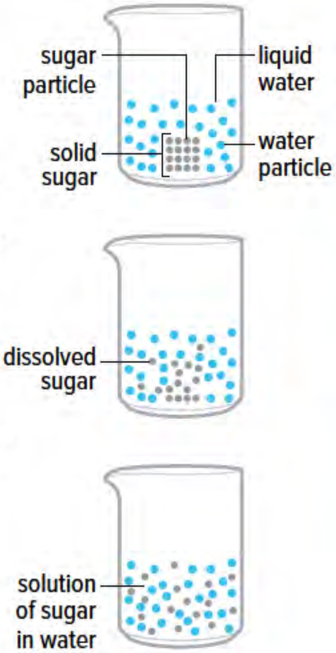


Figure 2.18 Kinetic molecular theory can help you visualize and explain what is happening to a sugar cube as it dissolves. **Why does sugar dissolve faster in hot water?**

Explaining Diffusion

Have you ever come home and instantly known what was for dinner just by the smell? The spreading of smells is an example of *diffusion*—the movement of one material through another. Why and how does the smell of fried onions or toasted bread travel from their sources to your nose? Odours come from gases that have characteristic smells. During cooking, those gases are released. Because gas particles move freely and quickly, those particles spread throughout the room.

Connect to Investigation 2-G on pages 150–151

Explaining Thermal Expansion

Solids, liquids, and gases normally expand when they are heated, and contract when they are cooled. This means that the hotter most substances get, the more their volume increases. The colder they get, the smaller their volume. The expansion of heated materials is called *thermal expansion*.

In places such as British Columbia, where temperatures can range from very cold to very hot, engineers must consider thermal expansion when building bridges and other structures. Repeated expansion and contraction can weaken building materials such as concrete, which can cause buckling, cracks, and breaks. Expansion joints such as the one shown in Figure 2.19 allow materials to expand and contract as the temperature changes without damaging the overall structure.

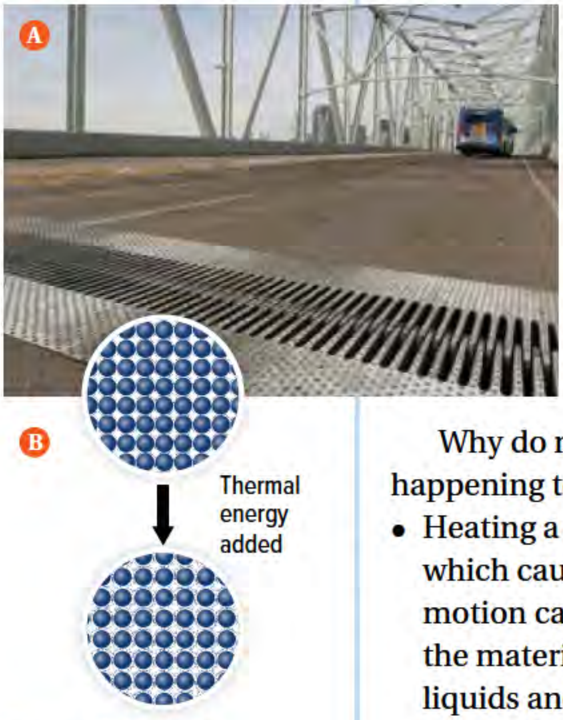


Figure 2.19 Ⓐ This expansion joint prevents damage by allowing the material in this bridge to expand and contract freely with changes in temperature. Ⓑ When a solid is heated, its particles gain energy and vibrate faster. They move farther apart and the solid expands as a result.

Why do materials expand when they get hotter? What is happening to the particles of those materials?

- Heating a solid increases the kinetic energy of its particles, which causes them to vibrate faster. This increase in vibrational motion causes the particles to move slightly farther apart, and the material as a whole expands. The same thing happens in liquids and gases. Added energy increases their motion, and the particles move farther apart.
- Liquids expand more than solids, because their particles move more freely and can move farther apart from one another.
- Gases can expand indefinitely, but gases heated in rigid containers cannot expand more than the walls of their containers allow. The particles collide with greater and greater force with the container walls, which means that the pressure on the inside of the container increases. If the pressure becomes great enough, the container will explode.

Before you leave this page . . .

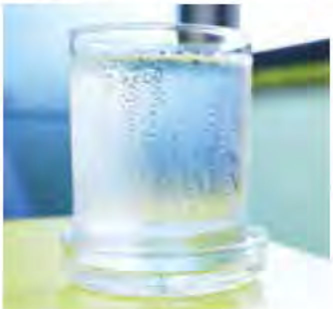
1. Use KMT to explain why a balloon in a hot car will expand and may eventually pop.
2. Use the KMT to explain what happens when salt dissolves in water.
3. The thermometers you use in the lab likely contain a narrow column of red-dyed alcohol. Use the KMT to explain how this type of thermometer works.
4. What might happen if a bridge were built in B.C. without an expansion joint? Explain.

Check Your Understanding of **Topic 2.3**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating AI Applying and Innovating C Communicating

Understanding Key Ideas

1. List the three main states of matter on Earth and describe the physical properties associated with each state. PA C
2. Identify a scientific model not mentioned or depicted in Topic 2.3 and briefly describe its purpose. E C
3. A liquid conforms to the shape of its container but does not expand to fill the container. Use kinetic molecular theory to explain why. PA C
4. A student sets a glass filled with ice water on a table. He notes that the outside of the glass is dry. The photograph below shows what the student observed after a short time had passed. Use the kinetic molecular theory to explain this observation. PA C



5. Use kinetic molecular theory to explain what happens when an ice cube is placed in a glass of warm water.
6. Some people use air fresheners in their cars with scents such as lemon, leather, or even "new car smell." One type of freshener consists of an ornament that has been infused with scented oil. Use the kinetic molecular theory to describe what happens when this type of air freshener is first removed from its package and hung from the rearview mirror of the car. PA C

Connecting Ideas

7. Use kinetic molecular theory to explain why puddles will eventually evaporate, even when the water never reaches the boiling point of water (100°C). Include diagrams in your explanation. AI C
8. A student freezes water in one ice cube tray and olive oil in another. She finds that the ice cubes float in liquid water while the olive oil cubes sink in liquid olive oil.
   - **a)** Compare the densities of the liquid and frozen water and the liquid and frozen olive oil.
   - **b)** Compare the two solids and liquids in terms of the differences in the spaces between their particles.
   - **c)** Most liquids behave like the olive oil when frozen. However, it is fortunate for life on Earth that water is an exception. Suggest one reason why.
   - **d)** List at least two science-related questions that you have based on this information.
   - **e)** Choose one question from part d) and describe how you would investigate to find an answer. QP PA E AI C

Making New Connections

9. The Mpemba effect is the name for a surprising observation: hot water freezes faster than cold water.
   - **a)** Why is this observation surprising?
   - **b)** Describe an experiment you could carry out to test this observation.
   - **c)** Conduct online research to find out how this effect got its name. PC AI C

TAKE a Stand

Make a Difference

Should perfume be banned in public places?

Freshly mown grass, window cleaner, wet dog, stinky socks, microwaved popcorn, wood smoke, perfume—these smells result from particles that enter the air from their sources and quickly diffuse outward. You smell them when the particles trigger the special sensors called olfactory receptors in your nose.

Take perfume as an example. Perfumes are scented oils dissolved in a mixture of alcohol and water. When you spray some perfume on your skin the alcohol and water evaporate quickly, leaving the scented oils behind. These evaporate too, but much more slowly. As the oils evaporate, their particles leave your skin and mix with the gases in the air. The particles diffuse quickly, and when some of them reach your nose, you smell the perfume.

Of course, you don't notice all the particles that reach your nose. Human olfactory receptors are not tuned to notice gases that we call "odourless," such as oxygen, nitrogen, carbon dioxide, or water vapour. But most people *do* notice and can identify a wide variety of smelly gases, including the many substances that make up a given fragrance. Some smells we like, others we don't. That's just life. But what happens when people complain that smells are affecting their health? Is that even possible?

Sweet or sickening?

The scent that one person loves to wear may, in fact, give another person a terrible headache.

The substances used in fragrances can be irritants and trigger allergy-like symptoms. In some people, fragrance sensitivity or intolerance may cause headaches, nausea, shortness of breath, muscle pain, or an itchy nose. People with asthma, bronchitis, emphysema, or allergies may be more sensitive to fragrances. Their symptoms can get worse when they smell fragrances. They may get a runny nose, muscle pain, shortness of breath, or nausea. If they are in direct contact with fragrances, they may get a bad skin rash.

In fact, according to one Canadian study, about 16 percent of the population are sensitive to environmental triggers such as strong odours. About 5 percent report that the triggers make them physically ill.

As well, some psychologists suggest that many people react to scents for psychological reasons rather than physiological ones. For these people, certain scents trigger anxiety, a psychological state that can cause physical symptoms, such as rapid breathing, higher heart rate, and even hyperventilation.

PERFU
NO
FRAGRANCES

Ban or not?

Nowadays many people see signs in the offices of their family doctor or dentist, in some classrooms, or in workplaces that ask them—or tell them—not to wear certain scents or fragrances. Currently there are no laws in Canada banning fragrances in the workplace. But scent sensitivity is becoming a human rights issue. Legal experts are advising employers to take complaints seriously and put in place fragrance-free policies. They suggest employers explain to employees that the banned fragrances are not simply unpleasant to others but can trigger serious medical problems.

Some people agree that it is fair and respectful to ban fragrances in certain places, such as workplaces, public libraries, places of worship, or hospitals. Others feel these bans are valid in workplaces where people have physiological reactions to scents but not if their reactions are psychological. What do you think?

Analyze and Evaluate

1. Should the health of people with scent sensitivities be protected by laws? What are the pros and cons of banning fragrances? If so, where should these laws apply? Support your ideas.
2. Should makers of common products (such as shampoos, body washes, air fresheners, cleaning products) for home and workplace use be forced to limit the use of fragrances in their products, or should consumers be allowed to choose whether or not to buy and use fragrance-free products? Support your ideas.
3. Should people's psychological reactions to smells be treated just as seriously as physiological reactions? Research the difference, and then explain your views.
4. What kind of effect can fragrances in products such as synthetic musk have on the environment?

Communicate

5. Decide how you could help increase public awareness about this situation. Conduct any research you need to decide on a plan. Write out your plan and, with your teacher's approval, carry it out.

INVESTIGATION

2-F

GUIDED INQUIRY

Modelling Changes of State

Safety

- To be identified by each student group as part of planning stage

What You Need

- To be identified by each student group as part of planning stage

The first two pages in this unit compared a marathon race with the changes that take place as a solid melts, forming a liquid, which then vapourizes. Analogies and models help us visualize and analyze processes we cannot see, such as what happens to the particles of matter when it changes state.

Question

How can you model changes of state as explained by the kinetic molecular theory of matter?

could you use billiard balls del changes of state?

Procedure

1. Work in groups. Your challenge is to create a model that can be used to demonstrate what happens during the changes of state, according to the kinetic molecular theory of matter. As a group, list the criteria that your model should satisfy. For example, the model should...
   - clearly demonstrate all of the possible changes of state among solids, liquids, and gases
   - show the main types of movement of the particles in each state
   - show the structure of matter in each state

2. Brainstorm some possible ways to make your model. For example, you could…
   - make a series of labelled illustrations on a poster
   - use software to make a series of simple animations
   - make a stop-action video using coins to represent particles
   - make a live-action video with people acting as particles
   - plan a game that has people acting as particles in various states
   - set up an interactive museum exhibit using marbles and various containers to represent the states and changes of state
3. Decide on what kind of model you want to make and come up with a detailed plan to make it. Your plan should include…
   - a list of materials you will need
   - safety precautions you will follow
   - steps you will take to make your model
   - sketches to illustrate how your finished model will work
4. With your teacher's approval, carry out your plan.

Process and Analyze

1. Test your model. Does it satisfy the criteria you outlined in step 1 of the procedure? If not, how can you improve the model so it does?
2. Repeat step 1 above until you are satisfied with your model.
3. Do any problems or limitations remain with your model that you were not able to address? Explain.

Evaluate, Apply, and Communicate

4. Present your model to the class. Allow time for questions and suggestions.
5. Based on the feedback you received, what modifications would you make to improve your model?

INVESTIGATION
2-G

OPEN INQUIRY

Diffusion and the KMT

Skills and Strategies

- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Never eat or drink anything in the laboratory.
- Clean up any spills immediately and inform your teacher.
- Dyes may stain clothing or skin.
- Have your procedure approved by your teacher before you begin.

What You Need

(Suggested)

- a variety of clear containers
- graduated cylinders
- dyes of various colours
- thermometer
- stopwatch

500 mL
400
300
200
100

Planning and performing a controlled experiment lets you investigate your own question about diffusion.

Question

You will determine your own question to investigate. See step 1 of the Procedure.

Procedure

1. Your teacher will provide a collection of materials and equipment for you to examine. Think of a question about diffusion that you can investigate using some of the materials provided. Choose one of the questions below or come up with your own:
    - How is the rate of diffusion in water affected by the temperature of the water?
    - How long does it take for dye to diffuse completely in different volumes of water?
    - Do different colours of dye diffuse at different rates in water?
2. Write a procedure to describe how you will carry out an experiment to answer your question. Be sure to consider and include the following details in your procedure:
    - What materials will you need?
    - What safety precautions will you need to take?
    - What variables are involved? How will you control all but one variable?
    - What steps will you take as you carry out your experiment?
    - How many times will you repeat your experiment?

- How will you record your observations? For example, you might fill out a table, take point-form notes, make sketches, take photographs, take a video, or do some combination of these.
- How will you analyze and communicate your results?

3. Write a hypothesis for your experiment. A hypothesis states what you think will happen and why. You can phrase your hypothesis using an “If… then…” format. Use the kinetic molecular theory to help you frame your hypothesis.
4. With your teacher’s permission, carry out your procedure. Clean up as directed.

Process and Analyze

1. Compile your data into an organized form such as a table or graph.
2. Are you able to answer your question based on the results of your experiment? Explain why or why not.
3. Discuss whether and why your hypothesis was correct or not. Does the kinetic molecular theory of matter help you explain your results? Discuss why or why not.

Evaluate and Communicate

4. Write a lab report to communicate your findings based on the template provided by your teacher or using these headings: Title, Introduction, Question, Hypothesis or Prediction, Materials, Safety, Procedure, Results, Analysis, Conclusion. Be sure to incorporate images as appropriate, and include links to any videos you took if possible.
5. If you were to repeat your experiment, what changes would you make? Explain why you would make those changes.

TOPIC 2.4

How can we investigate and explain the composition of atoms?

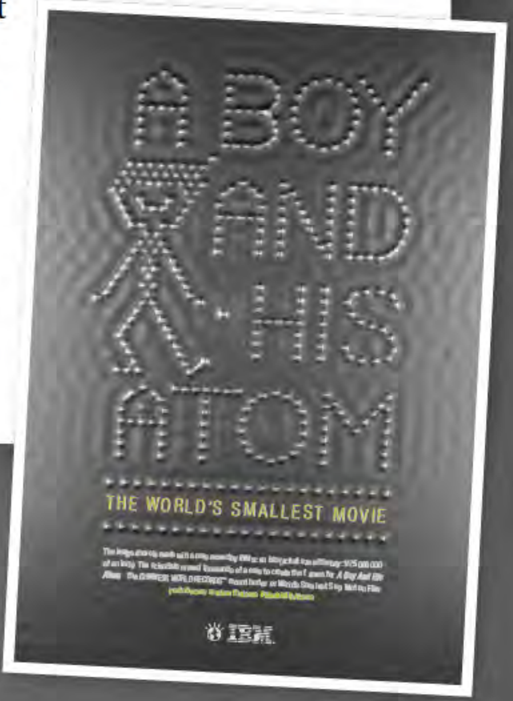
Key Concepts

- Dalton developed an early atomic theory.
- Many scientists contributed to the further development of atomic theory.
- An atom is made up of electrons, neutrons, and protons.
- Atomic theory continues to develop.

Curricular Competencies

- Seek patterns and connections in data from your own investigations and secondary sources.
- Transfer and apply learning to new situations.
- Generate and introduce new or refined ideas when problem solving.
- Communicate ideas using scientific language and representations.

This is a frame from the smallest stop-motion animated movie in the world: "A Boy and His Atom." Just how small is the movie? The dots you see here are oxygen atoms, each one the visible portion of a carbon monoxide molecule. Scientists moved them bit by bit, frame by frame, capturing the images using a powerful high-tech microscope. Being able to capture images of individual atoms and move them around with precision would have been jaw-dropping to scientists working in the late 1800s and early 1900s. Even so, with the technologies and techniques available to them at that time, scientists were able to imagine, plan, and conduct experiments to probe the structure of the particles that make up matter. Even today, we use the ideas and theories they developed to explain the properties and behaviour of the matter all around us.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The questions below involve scientific theories.
   - What is the difference between a scientific law and a scientific theory?
   - What is a hypothesis and how is it different from a scientific theory?
   - What is the relationship between a prediction and a theory?
2. **Questioning and Predicting** What questions do you have about how and why “A Boy and His Atom” was made? Record at least three questions and investigate them online.
3. **Evaluating** List two observations about matter that can be explained using kinetic molecular theory and two observations that cannot.

Key Terms

There are five key terms that are highlighted in bold type in this Topic:

- electrons
- nucleus
- protons
- neutrons
- atom

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Dalton developed an early atomic theory.

Activity

Explaining Differences in Matter

Your teacher will provide you with three different white solids. Examine the solids using a magnifying glass. How would you describe each solid? How are they different and how are they the same? Add vinegar to a small amount of each and describe what you observe. With your teacher's permission, heat a scoopula-tip's worth of each substance on a piece of foil on a hot plate and describe what you observe. Summarize your observations in a table. Does kinetic molecular theory help you explain the differences you observed?

The kinetic molecular theory of matter is based on the idea that matter is made up of tiny particles in motion. This theory does a good job of explaining why substances can exist in different states, and what happens when matter changes from one state to another. But there are many observations about matter that it cannot explain. For example, it does not explain why water and mercury have such different properties, even though both are liquids. Water is essential to life, while even small amounts of mercury can be deadly. Figure 2.20 shows the difference in their densities. What causes these differences?

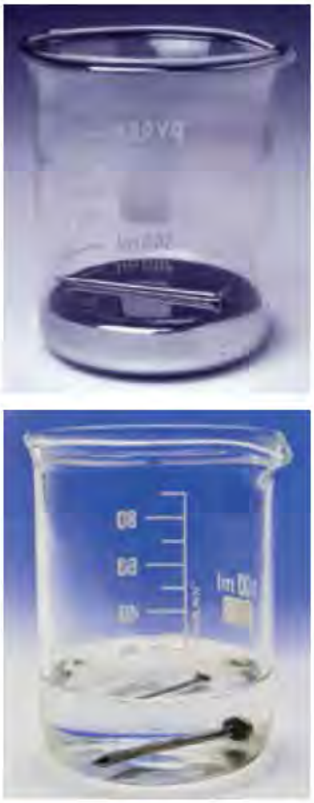


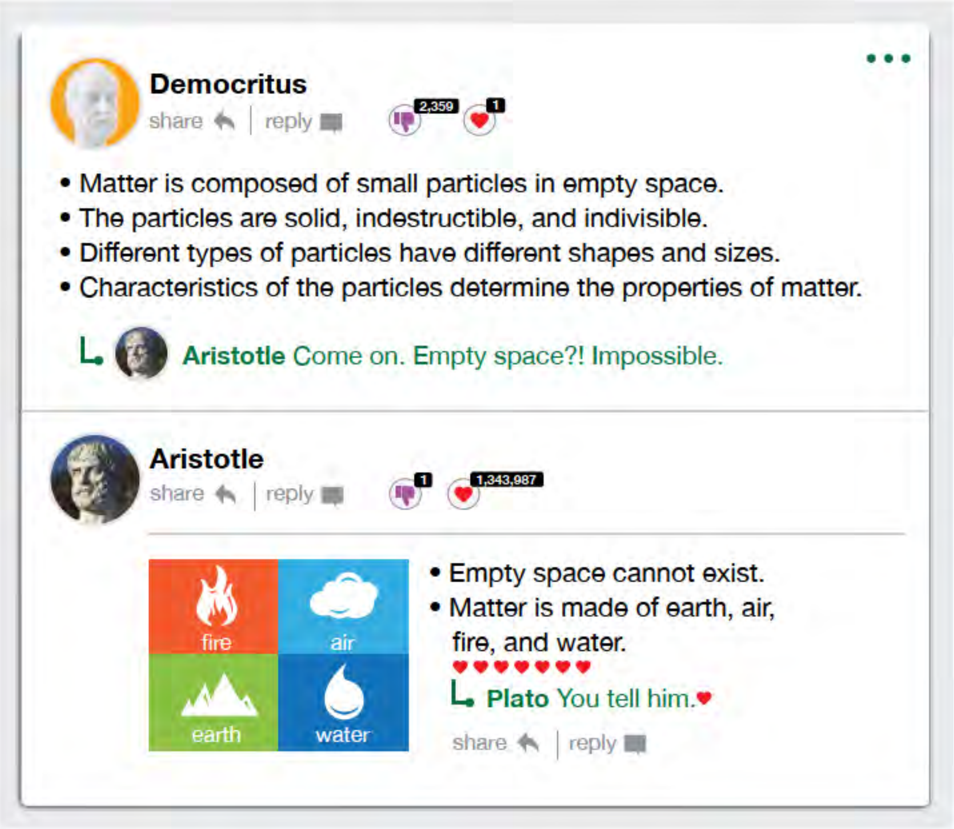
Figure 2.20 The kinetic molecular theory of matter cannot explain why mercury and water are so different.

Greek Philosophers and *Atomos*

Various peoples throughout history have used storytelling, philosophical debate, and other modes of communication and analysis to share and explore ideas about the properties and changes of matter. The idea that matter is made up of different kinds of tiny particles is actually thousands of years old. A Greek philosopher named Democritus proposed the idea that matter was made up of tiny particles that exist in empty space. He called these particles *atomos*, which means "uncuttable," because they could not be created, destroyed, or divided any further. Although this idea is similar to the idea of atoms that was developed by scientists in the 19th and 20th centuries, Democritus did not use experiments to support his ideas. As a philosopher, he used only reason and logic.

Philosophies of Matter

A well-respected and very influential philosopher, Aristotle, disagreed with Democritus's ideas, in large part because he did not believe that empty space could exist. Like many disagreements on social media today, the argument was won partly by popularity (**Figure 2.21**). In fact, Aristotle's influence was so great that his denial of the existence of atoms persisted for 2000 years.



Democritus

- Matter is composed of small particles in empty space.
- The particles are solid, indestructible, and indivisible.
- Different types of particles have different shapes and sizes.
- Characteristics of the particles determine the properties of matter.

Aristotle Come on. Empty space?! Impossible.

Aristotle

- Empty space cannot exist.
- Matter is made of earth, air, fire, and water.

♥♥♥♥♥♥♥

Plato You tell him.♥

Figure 2.21 If Democritus and Aristotle had been able to use social media thousands of years ago, their posts might have looked like this.

Atomic Theory Begins

Over the centuries, people in different countries read about the idea of *atomos*, and many (including some scientists) agreed with it. However, it was not until the early 1800s in England that the *atomos* idea reappeared with the support of experimental results and analysis. John Dalton (1766–1844), shown in **Figure 2.22**, was a schoolteacher and scholar. Unlike Democritus, he was able to conduct controlled scientific experiments. He could do this because the general methods of scientific inquiry had already been developed. He also had access to instruments such as glassware and accurate balances that enabled him to measure changes in matter.

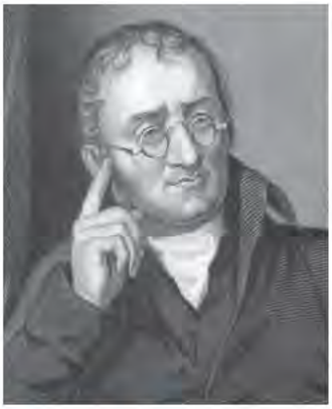


Figure 2.22 John Dalton

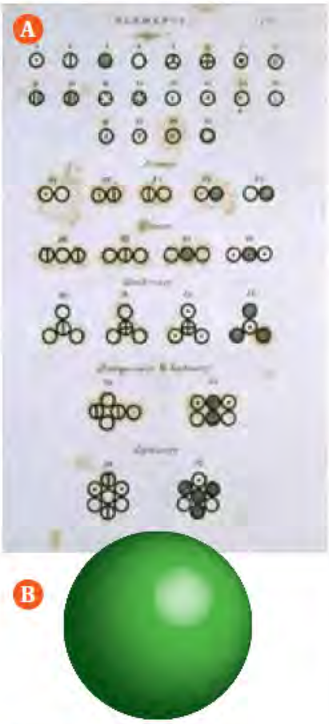


Figure 2.23 Ⓐ This page from Dalton's book, *A New System of Chemical Philosophy*, shows the symbols he used to represent atoms of different elements. Ⓑ According to Dalton's theory, atoms were solid, indestructible spheres.

Dalton's Theory of the Atom

Dalton's experiments allowed him to develop, refine, and support a hypothesis about matter. Studying many chemical reactions, he made careful observations and measurements that led him to propose in 1803 what has now come to be known as *Dalton's atomic theory*. He published his ideas in a book, a page from which is shown in **Figure 2.23**. The key points of his theory are described below.

Dalton's Atomic Theory

- All matter is made of extremely small particles called atoms.
- Atoms cannot be created, destroyed, or divided.
- All atoms of the same element are identical in size, mass, and chemical properties. Atoms of a specific element are different from those of another element.
- Different atoms combine in simple whole-number ratios to form compounds. In a chemical reaction, atoms are separated, combined, or rearranged.

Dalton's Theory Was Just the Beginning

Dalton's theory explained many existing observations about matter and its interactions. One example is the observation that mass is conserved in a chemical reaction—Lavoisier's law of conservation of mass. Since atoms were not created, destroyed, or divided in chemical reactions, it made sense that the mass of reactants and products in a chemical reaction did not change.

As scientists continued to study matter and to develop new technologies to allow them to perform different kinds of experiments, it became clear that Dalton's atomic theory could not explain all of the observations that scientists were making. Scientific theories are always subject to being changed or discarded if they prove insufficient to explain new observations. Dalton's atomic theory was just the beginning.

Before you leave this page . . .

1. Compare and contrast Democritus's *atomos* with Dalton's atomic theory.
2. How is a philosophical idea different from a scientific theory?

CONCEPT 2

Many scientists contributed to the further development of atomic theory.

Activity

Mystery Box

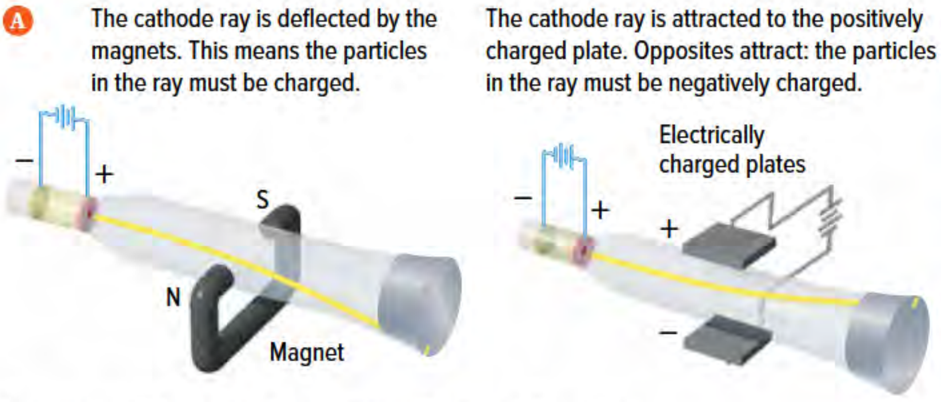
Your teacher will give your group a box, which you are not allowed to open. Using your skills of observation and the materials your teacher provides, perform as many tests as you can think of on the box to infer what is inside. How does this activity relate to the study of matter?

After Dalton got modern atomic theory rolling in the early 1800s, a series of discoveries followed that resulted in its adjustment and refinement. Throughout the remainder of the 19th century, many different scientists and inventors contributed to this work. A scientist named JJ Thomson was among the first.

JJ Thomson and the Electron

Joseph John Thomson (1856–1940) was a British physicist who studied electric currents in cathode ray tubes, as shown in Figure 2.24. Scientists had discovered that when they attached a battery to the tube, a ray travelled through the tube. They called this ray a *cathode ray* because it appeared to originate from the negative terminal or *cathode* in the discharge tube. Further experiments revealed the following:

- Cathode rays were streams of negatively charged particles.
- All substances produced these particles.



The cathode ray is deflected by the magnets. This means the particles in the ray must be charged.

The cathode ray is attracted to the positively charged plate. Opposites attract: the particles in the ray must be negatively charged.

The amount of deflection of the rays gave Thomson information about the ratio of the charge of the particles to their mass.

Figure 2.24 Ⓐ Thomson used magnets and charged plates to manipulate cathode rays and measure the effects. Ⓑ Fluorescent lights are familiar examples of cathode ray tubes.

Connect to Investigation 2-H on pages 168–169

Thomson's Model of the Atom

Thomson's key cathode ray tube experiments involved determining the charge-to-mass ratios of the negative particles. He did not determine the mass of the particles directly, but his experiments did allow him to compare their mass to that of a hydrogen atom, the lightest known atom. To his surprise, he found that the mass of the charged particles was much less than an atom of hydrogen. This meant that there were particles smaller than the atom! The conclusion was surprising because it contradicted the part of Dalton's theory that defined atoms as being indivisible. Based on the results of Thomson's experiment, Dalton's theory had to be revised, and a new model of the atom was developed.

Thomson proposed what he called a "plum-pudding" model of the atom. Plum pudding was a popular dessert in England at the time, but thinking of this model as a more familiar blueberry muffin gives the same results. Thomson's model, shown in Figure 2.25, pictured a positively charged ball (the "muffin") with negatively charged **electrons** embedded in it like blueberries. This model successfully explained the observations to date, but it soon had to be revised based on the findings of Thomson's student, Ernest Rutherford.

electrons negatively charged particles that are found in the space surrounding the nucleus

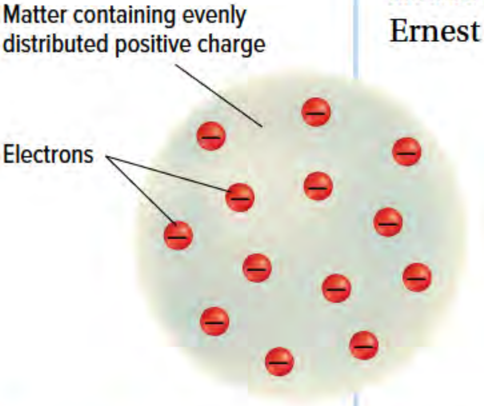


Figure 2.25 Thomson proposed a model of the atom similar to a blueberry muffin. Negatively charged particles (now called electrons) were embedded in matter with a positive charge that was evenly spread out.

Thomson's Contribution to Modern Atomic Theory
Atoms are not indivisible. They contain smaller, negatively charged particles, now known as electrons.

Ernest Rutherford and the Nucleus

Ernest Rutherford (1871–1937) was a scientist from New Zealand who worked for a while at McGill University in Montreal. In 1909 he designed an experiment to find out more about the structure of atoms. He exposed a very thin sheet of gold to a stream of high-speed particles with a positive charge, called alpha particles. The alpha particles acted like tiny bullets. Rutherford wanted to see what would happen to the alpha particles when they made contact with the gold atoms. He surrounded the gold foil with a detector screen. An alpha particle would become visible whenever it struck the screen. Figure 2.26 shows how the experiment was set up.

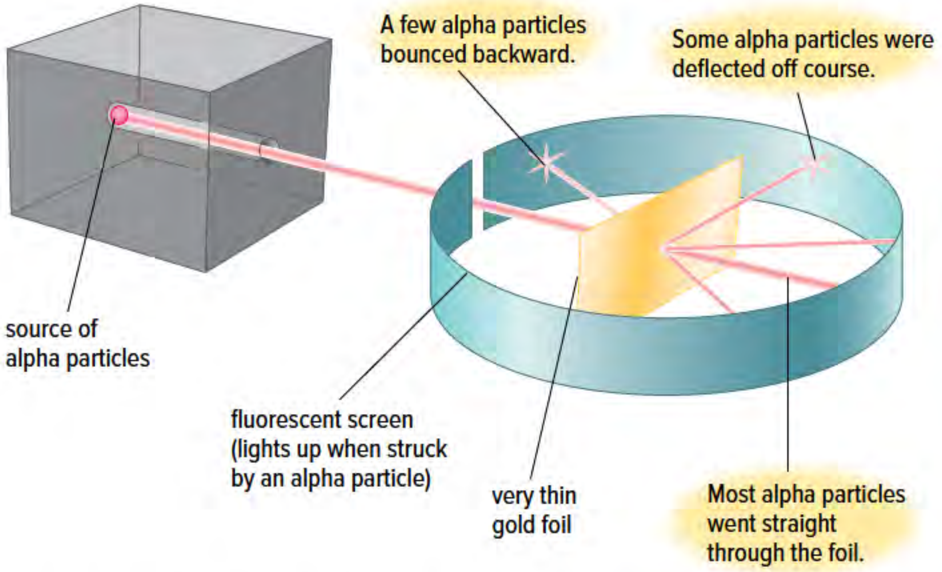

A few alpha particles bounced backward.
Some alpha particles were deflected off course.
source of alpha particles
fluorescent screen (lights up when struck by an alpha particle)
very thin gold foil
Most alpha particles went straight through the foil.

Figure 2.26 In Rutherford's experiment, most of the alpha particles went straight through the foil as expected. But a few bounced back, some at large angles. Rutherford had discovered the nucleus.

Most of the alpha particles went right through the gold atoms without their path being affected. This result was not surprising; it was consistent with Thomson's model. (Imagine a bullet going through a muffin.) The surprising result was that a small percentage of the alpha particles rebounded from the foil, much as a ball bounces off a wall. Rutherford had discovered the **nucleus**—the tiny, dense, positively charged centre of the atom.

Once again atomic theory had to be revised, and a new model of the atom, as shown in Figure 2.27, was proposed. According to Rutherford's model, virtually all of the mass of an atom was concentrated in the nucleus. The nucleus was so small compared to the volume occupied by the surrounding electrons that the majority of the atom's volume was empty space!

By 1920, it had been discovered that the nucleus contained positively charged particles that Rutherford called **protons**. James Chadwick (1891–1974), a coworker of Rutherford's, found that the nucleus also contained neutral particles called **neutrons**.

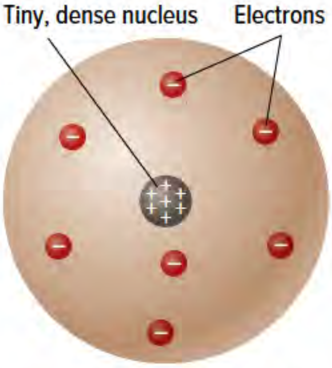

Tiny, dense nucleus
Electrons

Figure 2.27 Rutherford revised the model of the atom to include a dense nucleus with a positive charge that was very tiny compared to the overall size of the atom. Electrons moved freely in the space surrounding the nucleus.

Rutherford and Chadwick's Contribution to Modern Atomic Theory

The vast majority of an atom's volume is empty space occupied by very tiny negatively charged moving electrons.

The positive charge in an atom is contained in a tiny, dense nucleus. The nucleus is made up of two types of particles, each with about the same mass: protons, which are positively charged, and neutrons, which have no charge.

nucleus the positively charged centre of an atom that contains protons and neutrons; tiny compared with the size of the atom

protons positively charged particles found in the nucleus of an atom

neutrons particles with no charge that are found in the nucleus of an atom

Niels Bohr and Energy Levels

Niels Bohr (1885–1962) was a Danish physicist. While working as a student in Rutherford's lab, he studied electrons and the region around the nucleus. Bohr analyzed the results of experiments on the light released by various gases. In the experiments, the gases had been made to glow by passing an electric current through a low-pressure sample contained inside a glass tube. Each gas produced a characteristic spectrum of light as a result, called a *line spectrum*. The line spectrum for hydrogen is shown in **Figure 2.28**.

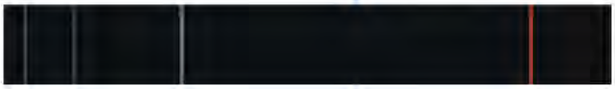


Figure 2.28 This line spectrum for hydrogen provides evidence that electrons can have only certain allowed energies.

The colour or wavelength of light is related to its energy. Bohr knew that the light emitted by the gases was a result of high-energy electrons releasing energy. But why did the electrons of a given gas emit light only of certain wavelengths? Rutherford's model of the atom could not explain this result because electrons could possess any amount of energy in that model.

Electron Energy Levels

As shown in **Figure 2.29**, Bohr proposed that electrons surrounding the nucleus could occupy only specific "energy levels" or "energy shells." Each energy shell was associated with a certain amount of energy. The larger the shell, the higher the energy of an electron occupying it.

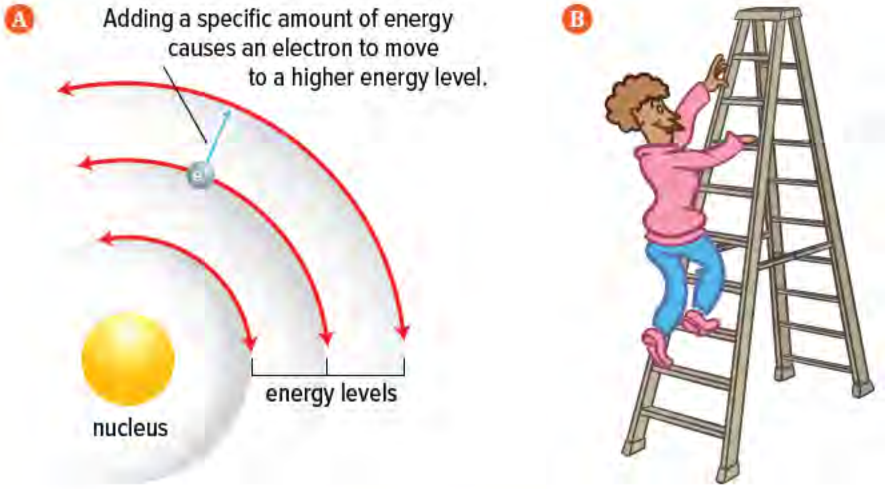

A
Adding a specific amount of energy causes an electron to move to a higher energy level.
e
energy levels
nucleus
B

Figure 2.29 Ⓐ In Bohr's model of the atom, electrons can have only certain amounts of energy. They occupy energy shells surrounding the nucleus. Ⓑ The energy shells are like rungs on a ladder. When you climb a ladder, your foot can rest on any of the rungs but not in between.

Bohr's Contribution to Modern Atomic Theory

Electrons can have only certain amounts of energy. They occupy defined energy levels or shells in the space surrounding the nucleus.

Visible Effects of Electron Energy Shells

A neon light is an example of the visible effect of electrons jumping from one energy level to another. When electricity is added to the neon gas, the electrons in the neon atoms gain energy, causing them to jump to higher energy levels. Electrons can then fall back down to lower energy levels, releasing energy in the form of visible light of a characteristic colour. The light is the evidence that the electrons exist in specific energy levels and can move from one level to another. The characteristics of the line spectra of various elements can also be used to identify them, as shown in Figure 2.30.

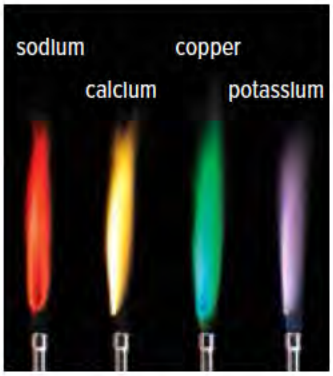


Figure 2.30 Flame tests work by placing a small sample of a compound containing a metal element in a flame. The added energy causes electrons in the atoms to jump up into higher shells and then fall back down, giving off light of characteristic colours.

Atomic Theory—A Group Effort

Bohr did not come up with his ideas in isolation—he built on the existing atomic model and theory, but also on work that Albert Einstein and others were doing regarding the nature of energy and light. Similarly, Thomson, Rutherford, and all of the other scientists who contributed to the development of modern atomic theory built on the work of scientists who had published results before them and who were working simultaneously on related ideas. They also depended on communication and teamwork with their colleagues, students, and laboratory assistants.

Activity

Atomic Theory Timeline

Working in groups, make a digital or paper timeline to show the development of atomic theory. Include the scientists and discoveries discussed in this book, but also research the contributions of additional scientists. You may wish to include some or all of the following people and events: Robert Boyle, William Crookes, Marie Curie, Robert Millikan, Eugen Goldstein, Lise Meitner, the first particle accelerator, the splitting of the uranium atom, the development of atomic weapons, the discovery of quarks and other particles, and the founding of CERN. Include any additional items you find through your research. You may also wish to include key historical events to anchor the events of the timeline, such as World Wars I and II.

Before you leave this page . . .

1. Compare and contrast models of the atom.
2. In your own words, describe Bohr's contribution to atomic theory.

CONCEPT 3

An atom is made up of electrons, neutrons, and protons

Activity

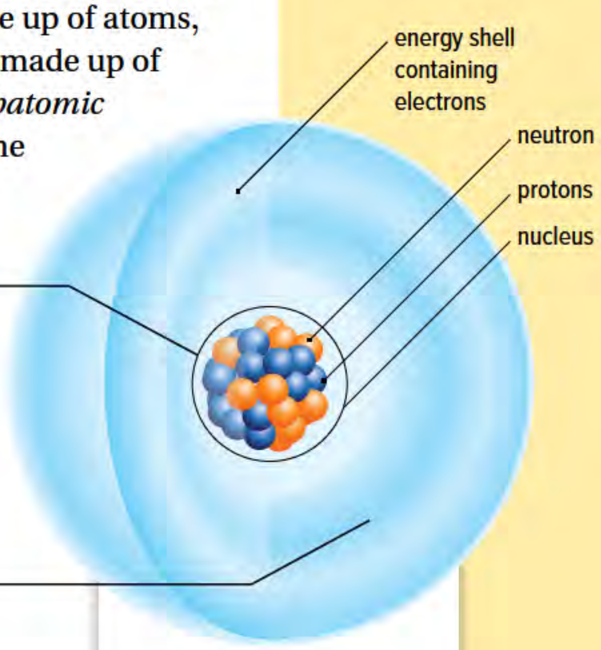
Cutting It Down to Size

Can you cut a piece of paper down to the size of an atom? Atoms vary in size, but a mid-sized atom is about 0.00000002 cm in diameter.

1. Take a strip of paper that is 25 cm long.
2. Predict how many times you would have to cut the strip in half to get a piece that is about 0.00000002 cm wide.
3. Start cutting. How many times were you able to cut your paper in half? How many more times would you have to cut to get your paper to the size of an atom?

atom the smallest particle of an element that retains the properties of that element

Today we know a lot about the nature and structure of atoms. An **atom** is defined as the smallest particle of an element that retains the properties of that element. All matter is made up of atoms, and atoms themselves are made up of smaller particles called *subatomic particles*. Key features of the atom are summarized in Figure 2.31.



nucleus

- The nucleus is the tiny region at the centre of the atom.
- The nucleus of most hydrogen atoms contains one proton.
- The nucleus of all other atoms contains both protons and neutrons.
- The number of protons in a nucleus determines the charge of the nucleus and the identity of an atom.

electron energy shell

- The region that electrons occupy accounts for well over 99.99 percent of the volume of an atom.
- Electrons occupy specific regions called energy levels that surround the nucleus.
- An electron is not like a fast-moving particle racing around the nucleus. It is more like a spread-out cloud of negative charge that exists in the whole region all at once.

Figure 2.31 This model of the atom will help you explain the observations you make about matter in your study of chemistry.

Electric Charge

Electric charge comes in two types: positive and negative. Protons have a positive charge (1+ each), and electrons have a negative charge (1– each). The positive charge of the protons in the nucleus attracts the surrounding electrons. Neutrons have no charge. Atoms have equal numbers of protons and electrons, and so overall an atom is uncharged or neutral.

The Size of an Atom

Atoms are incredibly small. Suppose you enlarged everything on Earth so that an atom would become as big as a large apple. At this new scale, an apple would be as big as Earth!

NATIONAL HOCKEY LEAGUE
OFFICIAL GAME PUCK

The Size of the Nucleus Compared with an Atom

If a nucleus were the size of a hockey puck sitting at centre ice, the whole atom would include the entire rink, the seats, the building, and the surrounding streets and walkways or parking lot.

The Nuclear Force

Nuclei include multiple positively charged particles—protons—that are very close together. Normally, charged particles that have the same charge repel one another very strongly. But a force called the *nuclear force* (also called the *strong force*) acts within the nucleus to hold protons and neutrons together. It is very strong across very short distances—strong enough to counteract the repulsion between protons, keeping the nucleus from flying apart.

Connect to Investigation 2-I on pages 170–171

Subatomic Particles

Name	Symbol	Electric Charge	Relative Mass	Location in the Atom
proton	p^+	1+	1836	nucleus
neutron	n^0	0	1837	nucleus
electron	e^-	1–	1	surrounding the nucleus

Before you leave this page . . .

1. What are the three subatomic particles?
2. Compare and contrast the electron and the proton.
3. Use an analogy to describe the size or composition of an atom.
4. What does the existence of a nuclear force explain?

CONCEPT 4

Atomic theory continues to develop.

Activity

Atomic Theory in the Future

Do you think atomic theory is likely to change in the future? Write a brief blog post explaining your position. Support your ideas with examples.

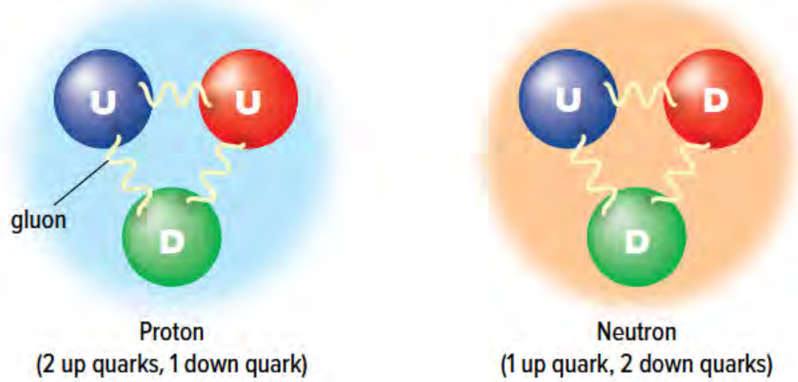
According to Dalton's theory, atoms were indivisible and indestructible. Then Thomson discovered the electron and Rutherford discovered the nucleus, which was later found to be made up of neutrons and protons. The atom was not indivisible at all: it was made up of even smaller particles—*subatomic particles*. As scientists continued to study matter throughout the 20th century, they discovered that some of these subatomic particles were made up of still smaller particles.

Quarks

You may have heard the term "quark" before, perhaps in the title of CBC Radio's science program, Quirks and Quarks. According to current theories, quarks are *elementary particles*, meaning that they cannot be split apart into smaller particles. There are six different types, called *flavours* (really!) of quarks. They are classified based on their properties, which include mass and electric charge, and have the following creative names: *up*, *down*, *strange*, *charm*, *top*, and *bottom*.

Protons and neutrons are known as composite particles. As shown in **Figure 2.32**, they are both made up of quarks. Protons and neutrons also contain elementary particles called gluons. These act as a "glue" that binds quarks to one another.

Figure 2.32 Protons and neutrons are made up of smaller elementary particles.



Leptons

Unlike protons and neutrons, electrons are themselves elementary particles. They are a type of elementary particle called *leptons*. Like quarks, leptons come in six flavours, as shown in Table 2.4. The key difference between quarks and leptons is that quarks experience the strong force, while leptons do not.

Table 2.4 Characteristics of Leptons

Lepton	Description
electron	• The electron is the lepton found in atoms. • Compared to the electron, muon and tau particles have the same charge (1^{-}) but a much greater mass.
muon	
tau	
electron neutrinos	• Neutrinos are very difficult to detect. They have no charge and are nearly massless. • Trillions of them pass through our bodies each second. • Neutrinos are produced by high-energy processes such as nuclear reactions in the Sun.
muon neutrinos	
tau neutrinos	

Research Continues

Today, engineers and scientists continue to work together to probe the atom even further. One local example, the TRIUMF cyclotron, is shown in Figure 2.33. Located in Vancouver, the cyclotron was built to research the particles that make up matter. Electromagnets in the cyclotron accelerate protons to extraordinary speeds. The resulting proton beam is allowed to collide with various materials, and specialized detectors provide data about the products of the collisions.

Figure 2.33 The TRIUMF cyclotron is a particle accelerator that produces a high-speed beam of protons. People come to Vancouver from all over the world to use it to run experiments.

Extending the Connections

Beyond the Atom

Choose one of these terms or another of your choice to research: dark matter, antimatter, the Higgs boson, superstring theory, or quantum mechanics.

Before you leave this page . . .

1. Describe the structure of a proton.
2. Compare neutrinos and electrons.

AT ISSUE

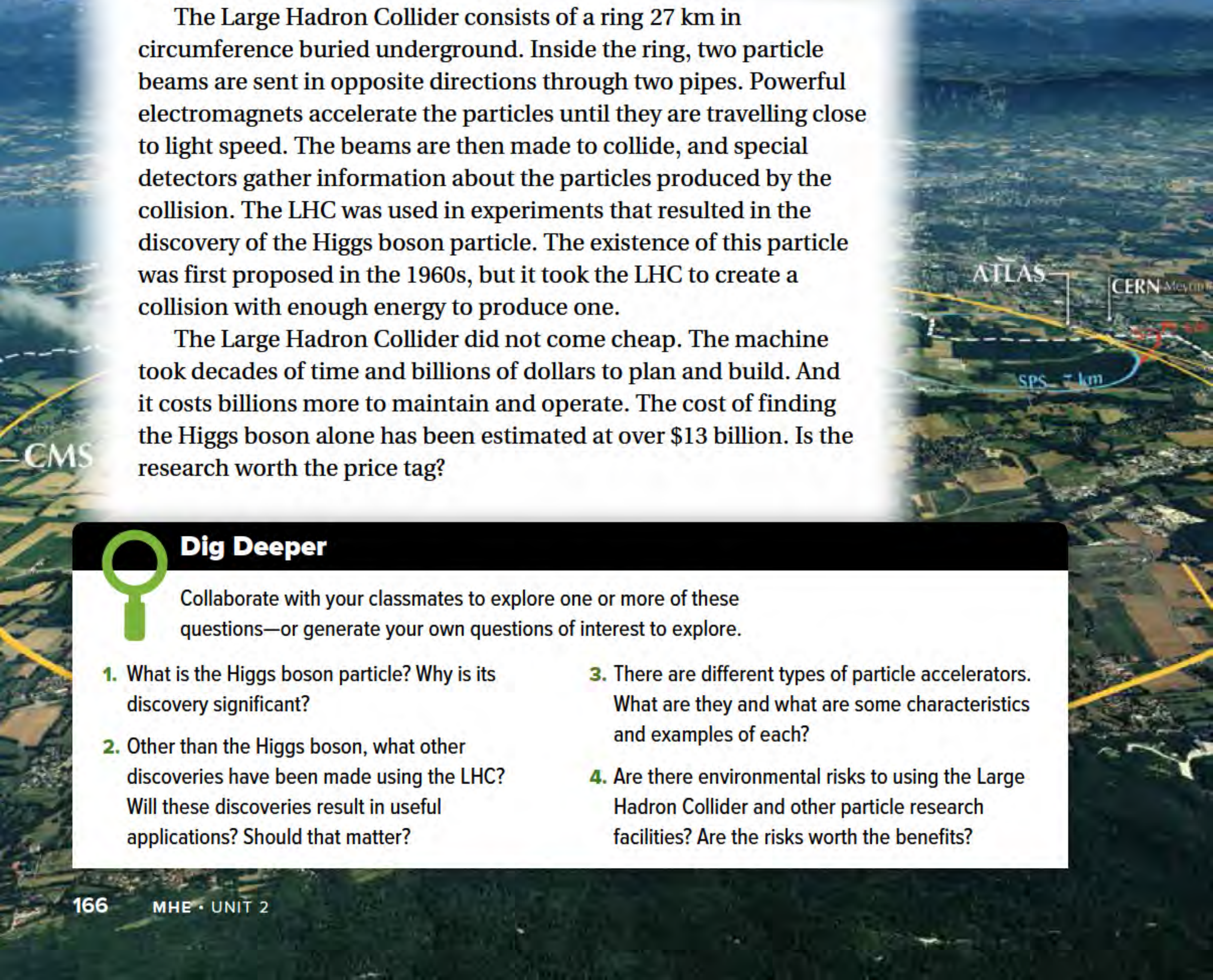
How do you smash subatomic particles—and why?

What's the Issue?

Strange but true: the job of the largest machine in the world is to study the smallest particles in existence. The machine is the Large Hadron Collider (LHC). It is a particle accelerator located on the border of France and Switzerland and operated by CERN, which stands for the French words for the European Organization for Nuclear Research.

The Large Hadron Collider consists of a ring 27 km in circumference buried underground. Inside the ring, two particle beams are sent in opposite directions through two pipes. Powerful electromagnets accelerate the particles until they are travelling close to light speed. The beams are then made to collide, and special detectors gather information about the particles produced by the collision. The LHC was used in experiments that resulted in the discovery of the Higgs boson particle. The existence of this particle was first proposed in the 1960s, but it took the LHC to create a collision with enough energy to produce one.

The Large Hadron Collider did not come cheap. The machine took decades of time and billions of dollars to plan and build. And it costs billions more to maintain and operate. The cost of finding the Higgs boson alone has been estimated at over $13 billion. Is the research worth the price tag?



Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. What is the Higgs boson particle? Why is its discovery significant?
2. Other than the Higgs boson, what other discoveries have been made using the LHC? Will these discoveries result in useful applications? Should that matter?
3. There are different types of particle accelerators. What are they and what are some characteristics and examples of each?
4. Are there environmental risks to using the Large Hadron Collider and other particle research facilities? Are the risks worth the benefits?

Check Your Understanding of **Topic 2.4**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Democritus's ideas about matter were amazingly close to modern atomic theory. Why did thousands of years pass before most people accepted his view? PA C

2. Use Dalton's model of the atom to explain the law of conservation of mass. PA C

3. Thomson's experiments with cathode rays resulted in a revised model of the atom. PA C

- **a)** What did Thomson discover about cathode rays?
- **b)** Why did this discovery mean that Dalton's model had to be changed?

4. Make a Venn diagram to compare Thomson's and Rutherford's models of the atom. PA C

5. What evidence supports Bohr's hypothesis that electrons can exist only in certain specified energy shells surrounding the atom? E C

6. Draw a labelled sketch to represent the atom as described in Concept 3. PA C

7. Compare and contrast protons and neutrons. PA C

8. Neutrons, protons, and electrons are all subatomic particles, but not all of them are elementary particles. PA C

- **a)** What is an elementary particle?
- **b)** Which particle in an atom is an elementary particle, and what type is it?
- **c)** Describe the structure of the other two particles in an atom.

Connecting Ideas

9. If Thomson's model of the atom had been correct, how would the results of Rutherford's experiment have been different? Use diagrams to illustrate your answer. E C

10. Of the three main subatomic particles that make up the atom (protons, neutrons, and electrons), why do you think the neutron was the last to be discovered? E C

Making New Connections

11. This giant sphere is a highly sensitive neutrino detector. It is located 2 km underground at the Sudbury Neutrino Observatory in northern Ontario. AI C

- **a)** Based on what you know about neutrinos, why do you think they are so difficult to detect?
- **b)** Neutrinos, along with many other high-energy particles, are constantly streaming at Earth's surface from space. Since this is the case, why do you think the neutrino detector is located so far underground?

INVESTIGATION 2-H

STRUCTURED INQUIRY

Skills and Strategies

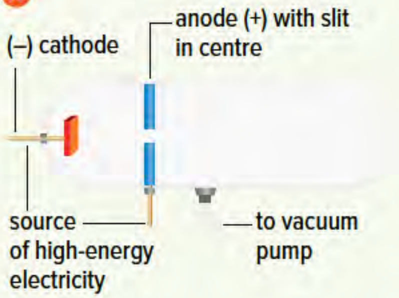
- Processing and Analyzing
- Evaluating
- Communicating

Interpreting Thomson's Results

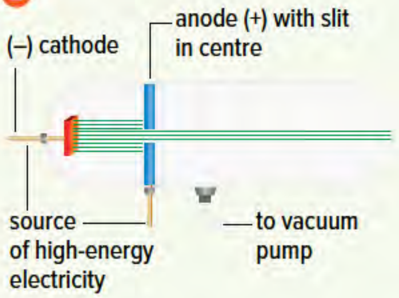
Question

How can 2-dimensional models (images) help you analyze JJ Thomson's experiments and their results?

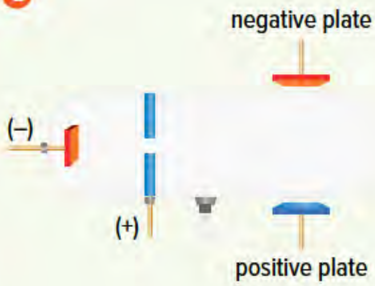
A


anode (+) with slit in centre
(–) cathode
source of high-energy electricity
to vacuum pump

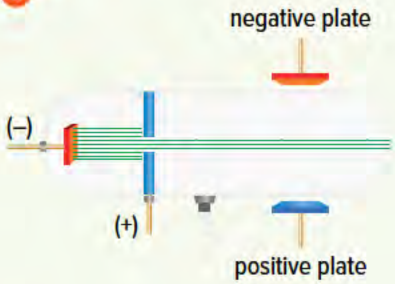
B


anode (+) with slit in centre
(–) cathode
source of high-energy electricity
to vacuum pump

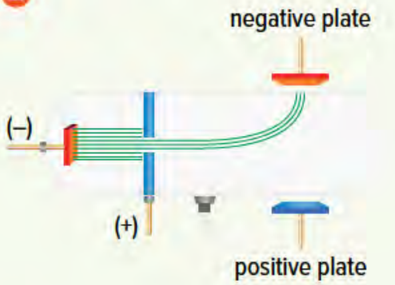
C


negative plate
(–)
(+)
positive plate

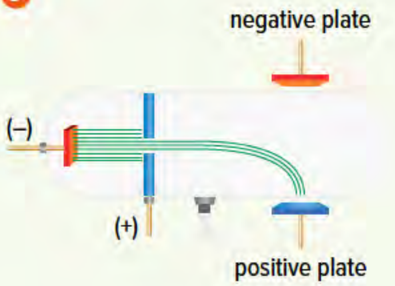
D


negative plate
(–)
(+)
positive plate

E


negative plate
(–)
(+)
positive plate

F


negative plate
(–)
(+)
positive plate

Procedure

1. Examine the photo and diagram A. The photo shows a cathode ray tube. (It is also called a Crookes tube after one of the scientists who invented it.)

   Compare and contrast the photo and the diagram.

2. Diagram B shows what happened when the source of high-energy electricity was turned on.
   - a) In which of these directions do the rays travel?
     - from the anode to the cathode
     - from the left-hand edge of the tube to the anode
     - from the source of electricity to the anode
   - b) Your answer to part a) is an example of an inference. An inference is a logical conclusion that you make based on evidence. What evidence supports your inference?
   - c) What does the slit in the anode do to the rays?

3. Diagram C shows additions Thomson made to the cathode ray tube in order to investigate the nature of the rays further. Describe the new equipment.

4. Only one of diagrams D, E, and F shows what happened when the apparatus was in use. Which diagram do you think predicts the outcome correctly? Give reasons for your choice.

Process and Analyze

1. Draw a sketch to show what you think would have happened if the negative plate were on the bottom and the positive plate were on top. Give reasons for your answer.

2. Earlier scientists had concluded that cathode rays carried a negative charge. Did Thomson's experiment support this conclusion? Support your answer with specific evidence from this investigation.

Evaluate, Apply, and Communicate

3. By measuring the path of the cathode rays, Thomson was able to confirm the rays' charge. He was also able to work out a relationship between the charge and mass of the particles. This relationship led to the discovery that the charged particles have barely 1/2000 the mass of one hydrogen atom.
   - a) Why was the mass of the particle significant?
   - b) What changes were made to Dalton's model of the atom as a result of Thomson's experiment and why?

4. Are simplified 2D diagrams of Thomson's apparatus and results helpful in understanding the experiment? Explain why or why not.

INVESTIGATION 2-1

GUIDED INQUIRY

Modelling the Atom

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Have your plan for making your model approved by your teacher before you begin.
- Use care if you are working with scissors or other sharp tools.

What You Need

- craft materials to make models
- materials to make posters
- a device with a camera and video recorder

Question

How can you use a variety of media to communicate the work of a scientist who advanced the understanding of atomic structure?

Procedure

1. Work in groups. Your teacher will assign your group one of the following scientists, or another of his or her choice:
   - John Dalton
   - William Crookes
   - JJ Thomson
   - Robert Millikan
   - Ernest Rutherford
   - Marie Curie
   - Niels Bohr
   - Henry Moseley
2. Your group's challenge is to produce a presentation about your scientist that includes a model of either the scientist's theory of the atom or a key experiment. Do research to find out about your scientist's contribution to atomic theory.
3. Collaborate to make a plan for doing the following:

   A. Making your model. Keep in mind the following criteria. The model should:
   - be detailed enough to show the key features of the scientist's atomic theory or experiment
   - be as dynamic as necessary, so that it can demonstrate the progress of an experiment, for example
   - illustrate the strengths and weaknesses of the scientist's work

   Your plan should include a list of materials you will need and sketches to show how you will make your model.

B. Giving your presentation. Consider including some of these features:

- a live or recorded simulated interview with your scientist
- a slideshow explaining the key points of your scientist's contributions
- a discussion of how your scientist fits into the larger picture of the development of atomic theory

You may wish to divide your group into two teams and have one team work on the model while the other works on the presentation. If you do this, decide how the two teams will communicate their progress to one another.

4. Check your plan with your teacher. Once it is approved, carry out your plan.

Analyze and Interpret

1. Practise your presentation and test your model. What improvements can you make?

Conclude and Communicate

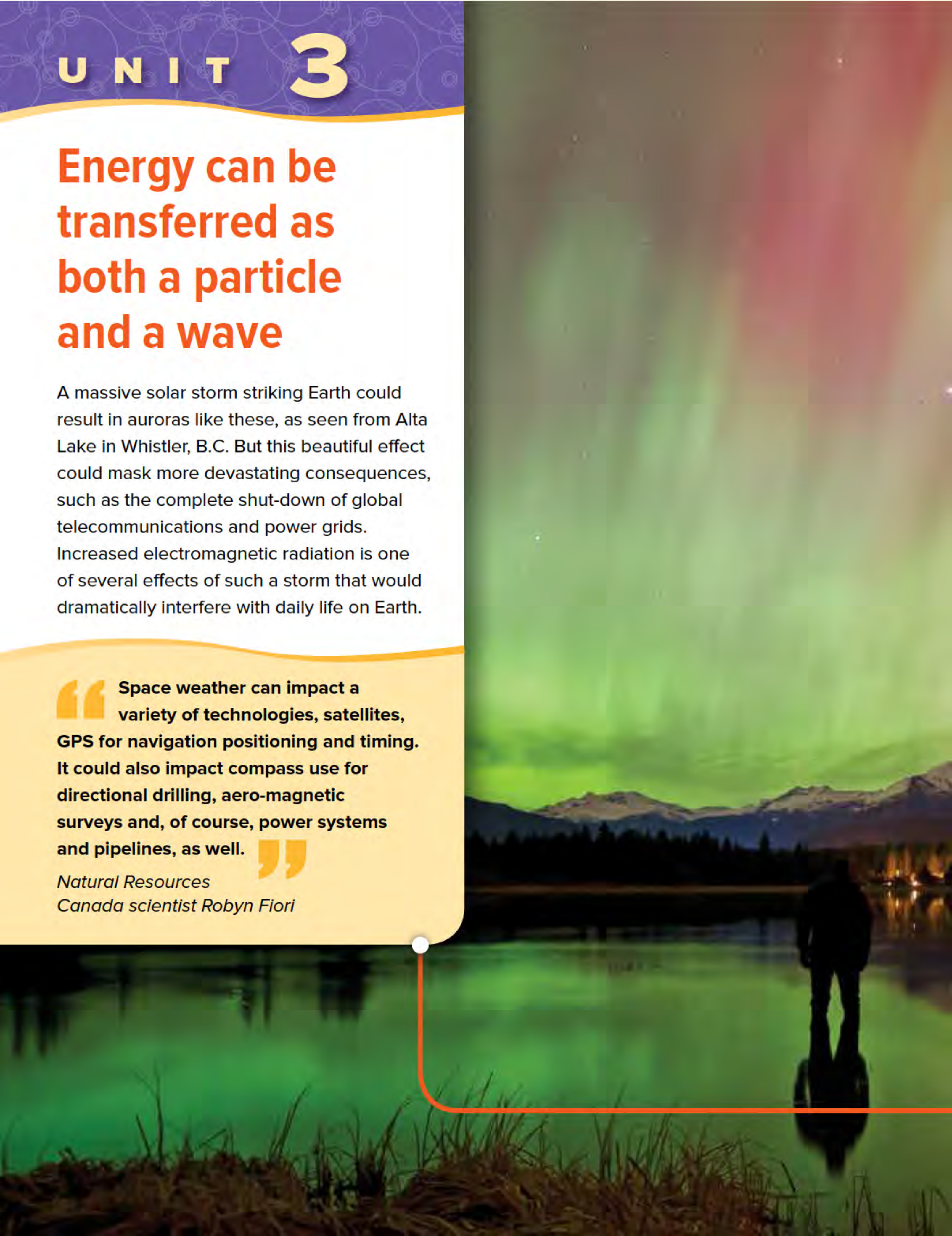
2. Give your presentation to the class. Be prepared to answer questions and receive feedback from the audience.
3. Based on the feedback you received, how would you change your presentation if you were to give it again?
4. Which group, other than your own, got across the scientist's key ideas most effectively? Explain your answer.
5. How well did your model demonstrate your scientist's work? What aspects of your model could you improve? Were there some limitations of your model that you could not overcome? Explain your answer.

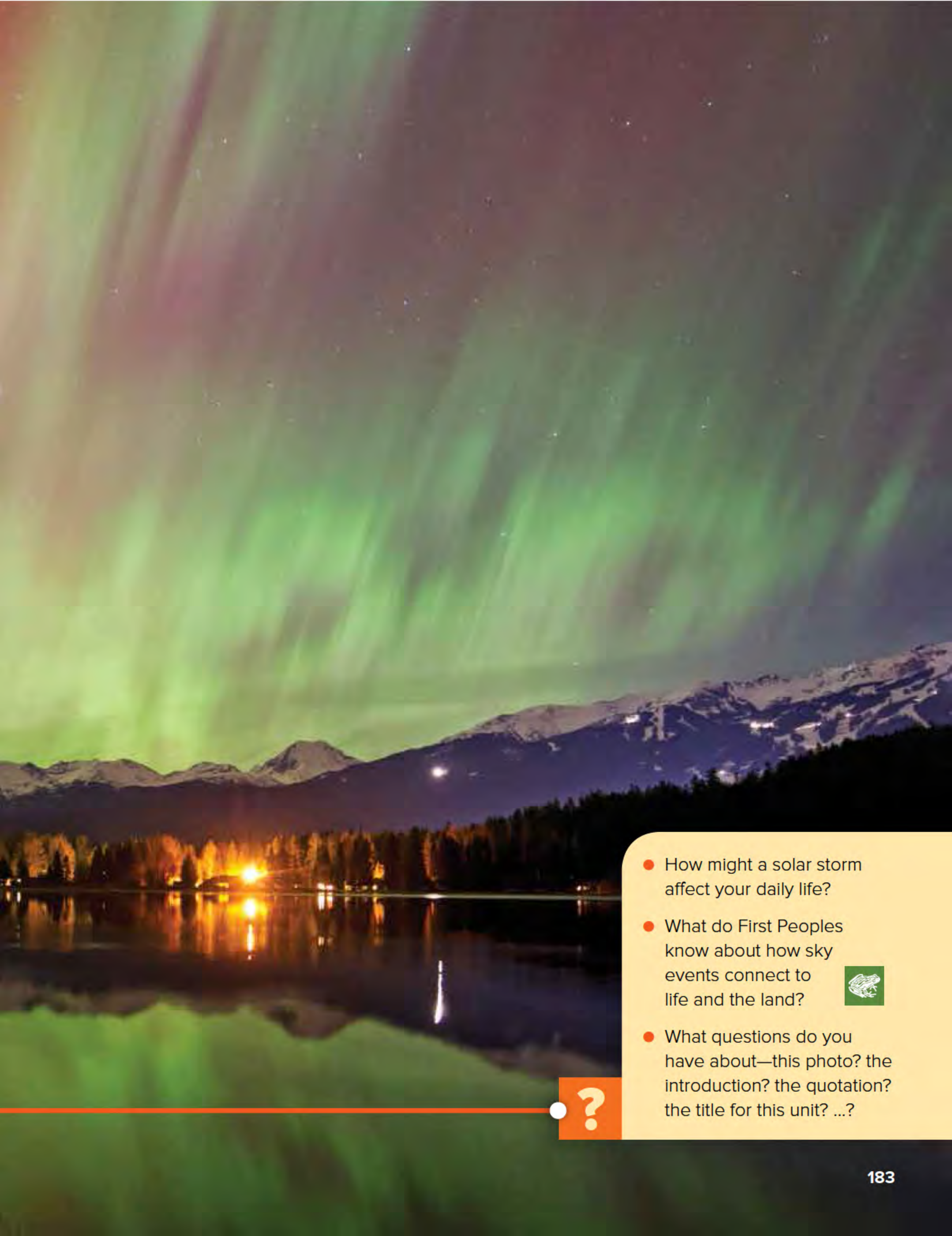
UNIT 3

Energy can be transferred as both a particle and a wave

A massive solar storm striking Earth could result in auroras like these, as seen from Alta Lake in Whistler, B.C. But this beautiful effect could mask more devastating consequences, such as the complete shut-down of global telecommunications and power grids. Increased electromagnetic radiation is one of several effects of such a storm that would dramatically interfere with daily life on Earth.

> **“Space weather can impact a variety of technologies, satellites, GPS for navigation positioning and timing. It could also impact compass use for directional drilling, aero-magnetic surveys and, of course, power systems and pipelines, as well.”**
>
> *Natural Resources Canada scientist Robyn Fiori*





- How might a solar storm affect your daily life?
- What do First Peoples know about how sky events connect to life and the land?
- What questions do you have about—this photo? the introduction? the quotation? the title for this unit? ...?

UNIT 3

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations to explore the nature and properties of electromagnetic radiation, with special emphasis on light
- Develop and use models and other methods to show connections between the types of electromagnetic radiation as well as show how energy can behave as both a wave and a particle
- Develop evidence-based explanations about the beneficial and harmful applications of electromagnetic radiation
- Use scientific understandings to describe, explain, and evaluate different ways we sense light

ESSENTIAL QUESTION

How can we investigate properties and applications of electromagnetic radiation?

TOPIC 3.1:
How does electromagnetic radiation shape your world?

Some things you will do:

- co-operatively design projects
- exercise a healthy, informed skepticism
- demonstrate an awareness of assumptions and identify bias
- connect scientific explorations to careers in science

Some things you will come to know:

- ways that electromagnetic radiation is an essential part of daily life
- how you use electromagnetic radiation to sense and make sense of the world

TOPIC 3.2:
How can models explain the properties of electromagnetic radiation?

Some things you will do:

- construct and use a range of methods to represent patterns or relationships in data
- identify a question to answer or a problem to solve through scientific inquiry
- demonstrate an understanding and appreciation of evidence

Some things you will come to know:

- how models can help you think about the way light and other types of electromagnetic radiation travel and behave
- why light and other types of electromagnetic radiation have properties of a wave as well as a particle

TOPIC 3.3:

How does light behave when it encounters different materials and surfaces?

Some things you will do:

- express and reflect on a variety of experiences and perspectives of place
- experience and interpret the local environment
- generate and introduce new or refined ideas when problem solving

Some things you will come to know:

- ways that light behaves when it interacts with different materials and surfaces
- how to distinguish among opaque, transparent, and translucent materials
- how sunsets, sundogs, and other optical phenomena occur

TOPIC 3.4:

How does light behave when it is reflected?

Some things you will do:

- seek patterns and connections in data
- use scientific understandings to identify relationships and draw conclusions
- make predictions about inquiry findings
- reflect on your investigation methods

Some things you will come to know:

- the laws of reflection
- characteristics of images reflected from different mirrors
- examples of technologies that apply reflection of light

TOPIC 3.5:

How does light behave when it moves from one medium to another?

Some things you will do:

- contribute to care for self, others, community, and the world
- observe, measure, and record data
- transfer and apply learning to new situations

Some things you will come to know:

- what happens when light travels through different media
- the role of refraction in human vision
- examples of technologies that apply refraction of light

UNIT 3

Summary

ESSENTIAL QUESTION

How can we investigate properties and applications of electromagnetic radiation?

TOPIC 3.1:

How does electromagnetic radiation shape your world?

- Electromagnetic radiation is an important part of your world.
- Sources of electromagnetic radiation are all around you.
- Electromagnetic radiation enhances how we sense our world.

Key Term

electromagnetic radiation

TOPIC 3.2:

How can models explain the properties of electromagnetic radiation?

- Visible light can be used to model all types of electromagnetic radiation.
- The ray model of light explains that light travels in straight lines.
- The wave model of light explains that light has wave-like properties.
- The particle model of light explains that light has particle-like properties.

Key Terms

ray model of light	particle model of light
wave model of light	wavelength
amplitude	frequency

TOPIC 3.3:

How does light behave when it encounters different materials and surfaces?

- Light can be reflected, absorbed, transmitted, or refracted.
- Light behaves differently when it encounters transparent, translucent, or opaque materials.

Key Terms

reflection
absorption
transmission
refraction

TOPIC 3.4:

How does light behave when it is reflected?

- Light is reflected in predictable patterns.
- Light reflected by a plane mirror produces an image that is nearly identical to the object.
- Light reflected by curved mirrors behaves in unique ways.
- Many technologies take advantage of light's behaviour when it strikes a reflective surface.

Key Terms

laws of reflection
plane mirror
concave mirror
convex mirror

TOPIC 3.5:

How does light behave when it moves from one medium to another?

- Light changes direction and speed when it moves from one medium to another.
- Light refracts as it passes through lenses.
- Refraction plays a role in human vision.
- Many technologies take advantage of light's behaviour when it moves from one medium to another.

Key Terms

lens
converging lens
diverging lens

UNIT 3

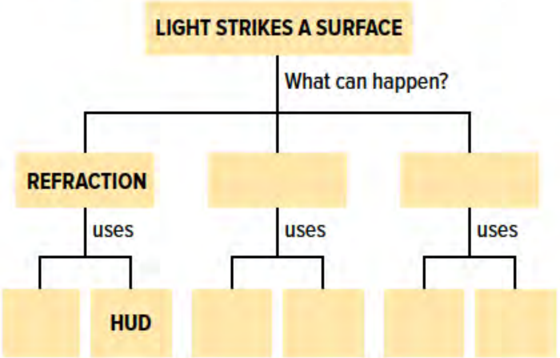
Review

What Do You Know?

Connecting to Concepts

Visualizing Ideas

1. Copy and complete the concept map.



2. Design a graphic organizer to show concepts that are related to the different types and properties of electromagnetic radiation.

Using Key Terms

3. Below are four sets of terms from this unit. For each set, write one or two sentences that use all the terms correctly.

a) transmission, converging lens, ray model of light, refraction

b) wave model of light, frequency, wavelength

c) concave mirror, focal point, real image

d) density, refraction, normal

Communicating Concepts

4. Explain the connections among the following terms as they apply to visible light: photons, particle model of light, wavelength.

5. The Sheringham Point Lighthouse on Vancouver Island is shown below. Explain why its light would look brighter to a ship that is 200 m away from it than one that is 800 m away.

6. Describe two beneficial uses and two dangers associated with different types of electromagnetic radiation.

7. Describe one way that light behaves like a wave, but not a particle.

8. Describe one way that light behaves like a particle, but not a wave.

9. Why do scientists talk about a wave model of light instead of saying that light is a wave?

10. Explain how a doctor could use electromagnetic radiation to diagnose a medical condition.

11. Describe the ray model of light and why it is useful.

12. Describe three ways that types of electromagnetic radiation are the same and three ways they are different.

13. Describe two ways a criminal investigator could use electromagnetic radiation to solve a crime.

14. Identify the type(s) of electromagnetic radiation that play a role in each of the following:

- **a)** sun tans
- **b)** skin cancer
- **c)** remote sensing
- **d)** the Internet
- **e)** astronomy

What Can You Do?
Connecting to Competencies

Developing Skills

15. **a)** A student uses a rope to produce a wave. Five complete wavelengths pass a point in one second as the wave goes by. Draw a model of the rope wave. Include labels to indicate its wavelength and frequency.

b) Draw a model of a rope wave with a longer wavelength and lower frequency than in part a). State a frequency that would make sense for the model you drew.

16. The archerfish below catches an insect by spitting a stream of water at it to knock it off an overhanging plant. The insect falls in the water, and the fish eats it. The eyes of the fish remain underwater when it hunts. Does the fish aim directly at the insect? Use a sketch to explain why or why not.

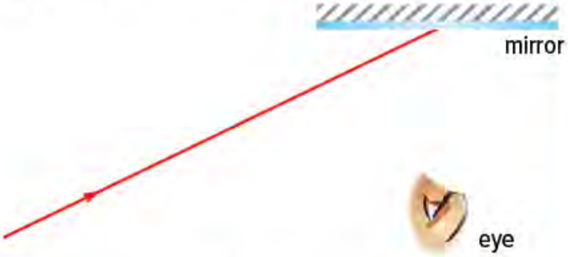
17. Design a demonstration that uses a ray of light and a plane mirror to show that the angle of incidence equals the angle of reflection when light reflects off a mirror. You can use any additional materials that you require. Include a materials list, safety guidelines, and a drawing of your set up.

18. Create a sketch that shows the path that visible light follows in the following cases:

- **a)** from the Sun to a mountain to the surface of a mirror-like lake to a viewer's eye
- **b)** from a desk lamp to a word on this page through a viewer's eye to the retina

Thinking Critically and Creatively

19. Imagine that the room in the diagram below is dark and has black walls. The air in the room is free from dust and smoke. A very narrow beam of light enters the room in the direction indicated by the ray. If you stay at the position indicated by the eye, can you see the mirror on the opposite wall? Explain why or why not.



20. A beam of light strikes a sample of matter.

- **a)** How many possible outcomes are there as light and matter interact?
- **b)** What happens to the light in each case?

21. Identify three sports in which the laws of reflection can be applied. For each sport, describe how these laws are applied.

Unit 3 Review *(continued)*

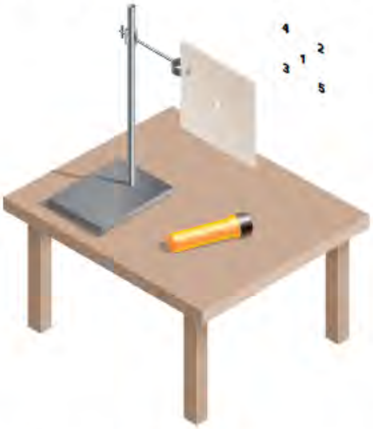
22. Name at least three skills from mathematics that you depended on as you studied electromagnetic radiation and light in this unit. Explain how your understanding of this unit might have been different if you did not have or know about these math skills.

23. At truck inspection stations and border crossings, security guards often need to see the underside of large semi-trailers and other vehicles.

a) How might they use a mirror to see under the vehicles?

b) What type of mirror would work best for this application? Use a drawing to support your response.

24. The equipment in the diagram below was set up for an experiment to demonstrate that light travels in a straight line. Infer how the experiment probably works. Explain your reasoning.



25. Sometimes, on a sunny day, campers start a campfire using a lens to light paper or dry grass.

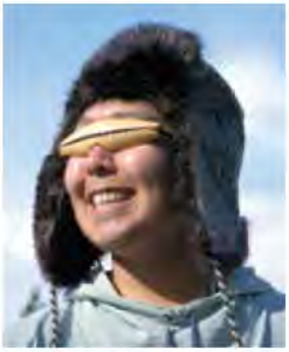
a) What type of lens do you think would work best for this application?

b) What is happening to the sunlight when it passes through the lens? Draw a sketch to illustrate your answer.

Understanding Big Ideas

Making New Connections

Applying Your Understanding



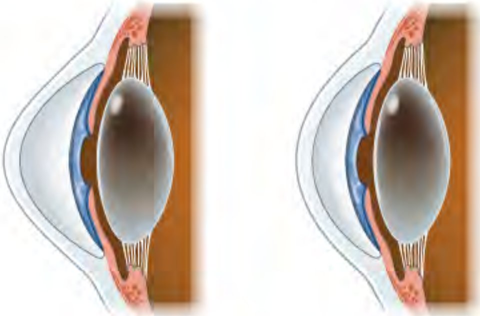
26. The first-known sunglasses were invented at least 2000 years ago by the Inuit to avoid snow blindness. Snow blindness is a painful, usually temporary condition caused by too much ultraviolet light getting into the eyes. The condition is more likely to occur in winter, when there is snow on the ground.

a) Why is snow blindness more likely to occur when snow is on the ground?

b) Infer from the photo how the design of Inuit snow goggles helped protect the eyes.

c) Soot was often rubbed on the eye slit. What would be the purpose of that?

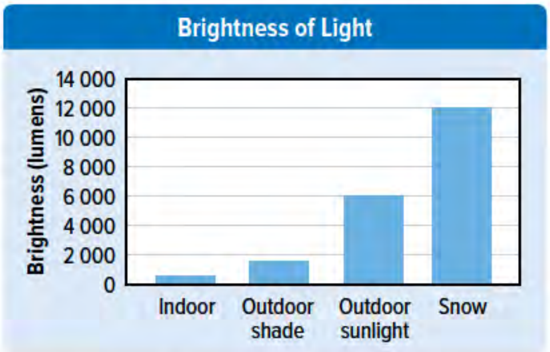
27. The diagrams below show two eyes. One has defective vision. Identify this eye, explain why you chose it, and explain how the defect could be corrected.



Thinking Critically and Creatively

28. Describe how curved mirrors could be used to increase safety on winding roads through mountainous regions.

29. Sunglasses are tinted to reduce the amount of visible light that reaches your eyes. The tinting is made up of light-absorbing substances. But the substances do not block eye-damaging ultraviolet radiation. Sunglasses with UV-filtering lenses let visible light pass through and absorb UV radiation.


Brightness of Light

a) The graph compares the brightness of light, measured in units of lumens, in different places. Most eyes are comfortable up to about 4000 lumens. After that, people start to squint. How bright is light reflected from snow? How would that brightness of light make your eyes feel?

b) What argument could you make to persuade people who do not wear sunglasses with UV-filtering lenses that they should?

c) Wraparound sunglasses offer more protection than standard ones. Explain why that is the case, and why wraparound sunglasses would be especially useful when water- or snow-skiing and when at the beach.

Connecting to Self and Society

30. How many different ways have you used and been affected by electromagnetic radiation today? List as many ways as you can, explaining a little bit about each one. See if you can come up with at least 20 (yes, you read that correctly).

31. Read and reflect on the paragraph below. Then write a paragraph describing your views in response to this question: "Should scientists receive funding to do scientific inquiry on concepts that have no apparent application?"

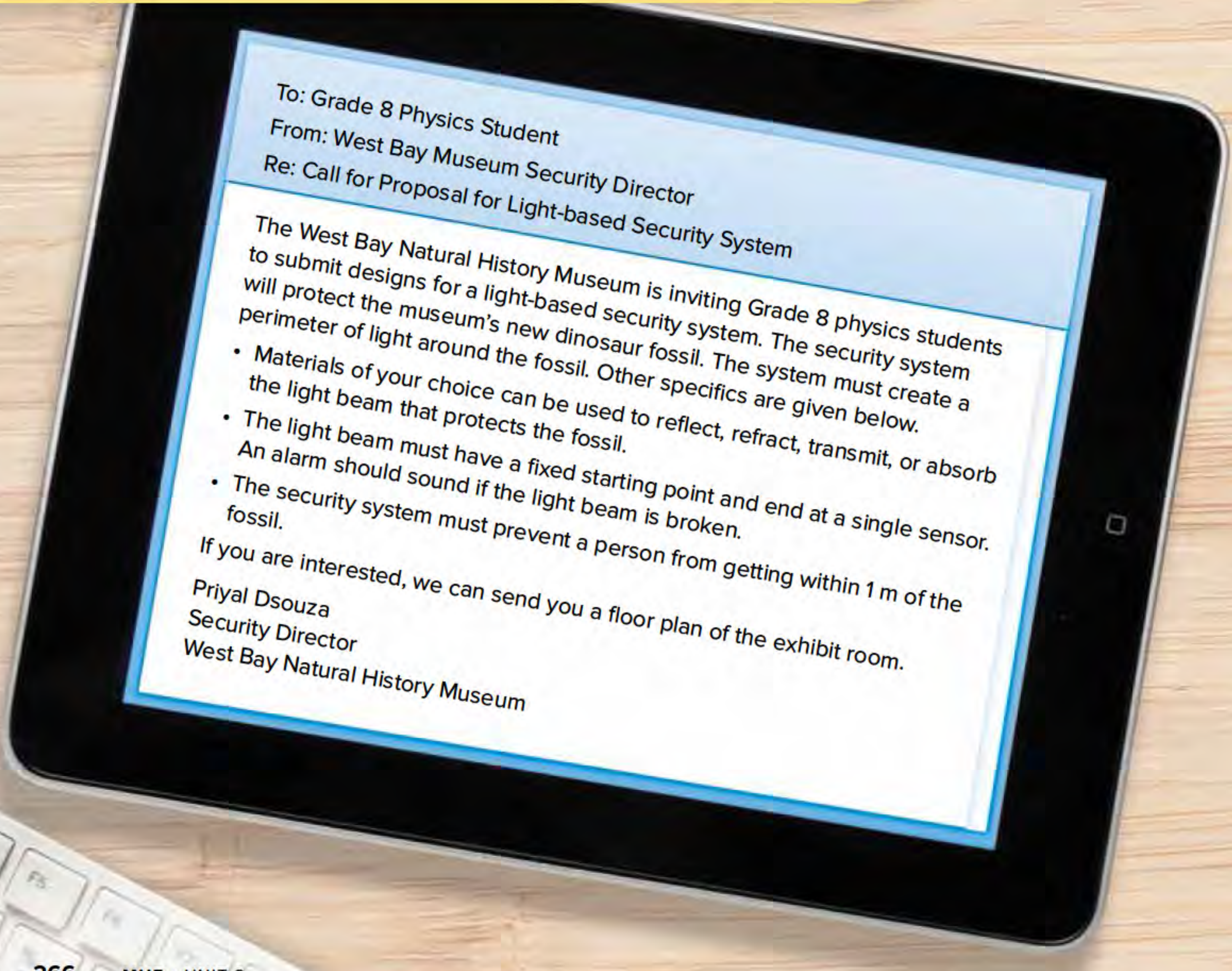
When scientists were researching certain wave and particle properties of light in the 1950s, the work they were doing was described as "a solution looking for a problem." They had no idea how their discoveries could be applied. By 1960, they had invented the laser, and it took at least another 30 years before this invention began to transform the way people live and communicate around the world. Barcodes, smart phones, surgical techniques, light shows, music and video streaming—none of these and many other modern applications would exist without the laser.

32. Mirror-like surfaces are useful to society. They are often used in beneficial technology. However, they can also be a great deal of fun. Use what you learned about mirrors in this unit to design a funhouse for people to enjoy. Your design should use at least one plane mirror, one convex mirror, and one concave mirror. For each mirror, explain the effect it would create in the funhouse.

Unit Assessment

New Dinosaur Exhibit at West Bay Natural History Museum

The West Bay Natural History Museum has just received a rare dinosaur fossil. In the rush to build a new exhibit room for the fossil, the need for a security system was overlooked. Most of the exhibit budget has already been spent, so the museum is asking students to design a low-cost, light-based security system to protect the fossil.



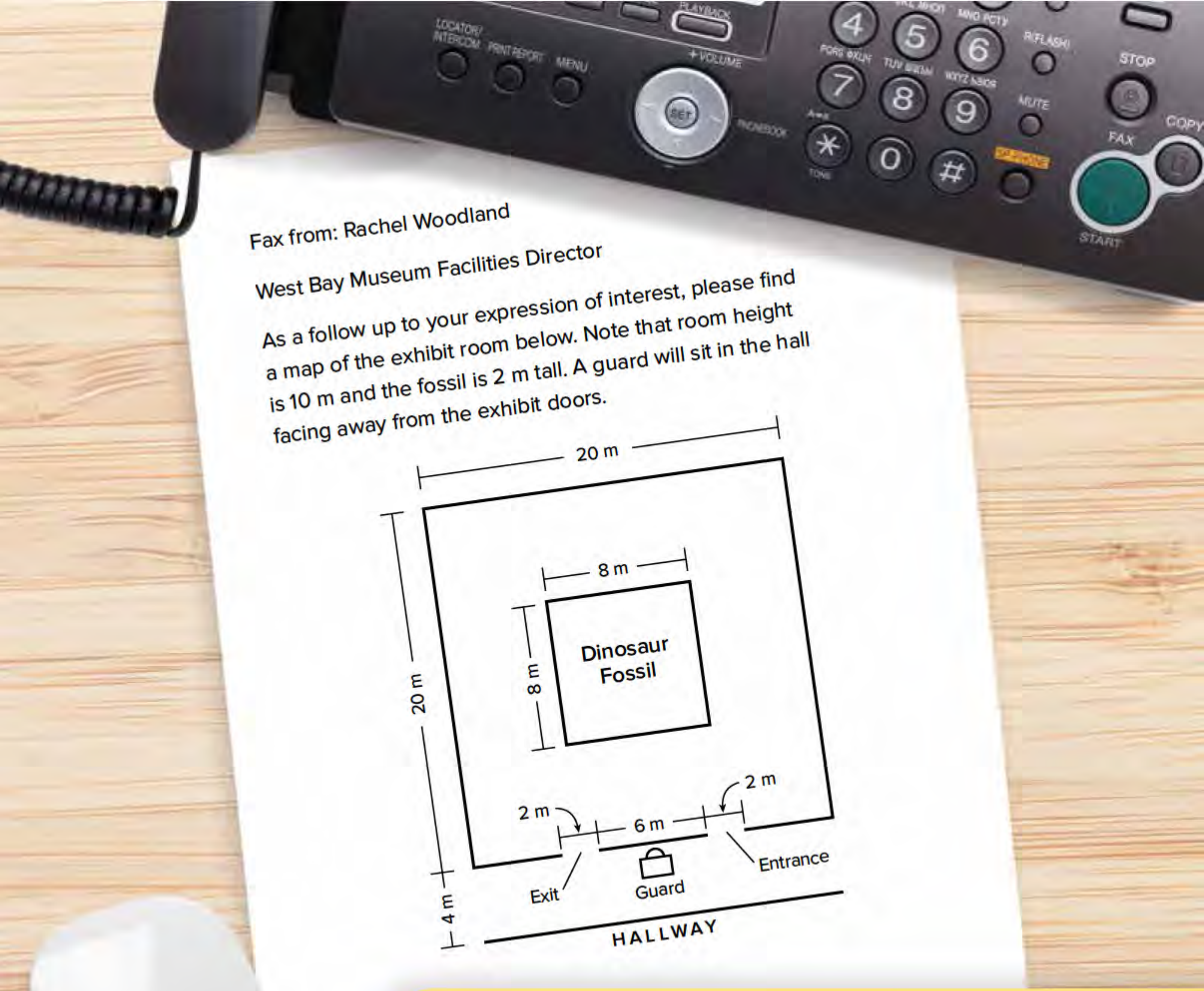
To: Grade 8 Physics Student
From: West Bay Museum Security Director
Re: Call for Proposal for Light-based Security System

The West Bay Natural History Museum is inviting Grade 8 physics students to submit designs for a light-based security system. The security system will protect the museum's new dinosaur fossil. The system must create a perimeter of light around the fossil. Other specifics are given below.

- Materials of your choice can be used to reflect, refract, transmit, or absorb the light beam that protects the fossil.
- The light beam must have a fixed starting point and end at a single sensor. An alarm should sound if the light beam is broken.
- The security system must prevent a person from getting within 1 m of the fossil.

If you are interested, we can send you a floor plan of the exhibit room.

Priyal Dsouza
Security Director
West Bay Natural History Museum



Fax from: Rachel Woodland

West Bay Museum Facilities Director

As a follow up to your expression of interest, please find a map of the exhibit room below. Note that room height is 10 m and the fossil is 2 m tall. A guard will sit in the hall facing away from the exhibit doors.

Your Task

Your teacher will start the TimeStamp™ video when the task begins. Your task is to complete a promotional package for your security system, as described below. You will present these to the board of directors of the museum.

1. Create a promotional package for the security system. The format of this package is up to you, but it must include your team name and logo; a short sales pitch explaining how you applied knowledge from this unit to create your security system; a drawing of your security system using the floor plan provided.
2. If time permits, build a 3-D model that shows the path of the light beam and position of the hallway mirror(s).

TOPIC

3.1

How does electromagnetic radiation shape your world?

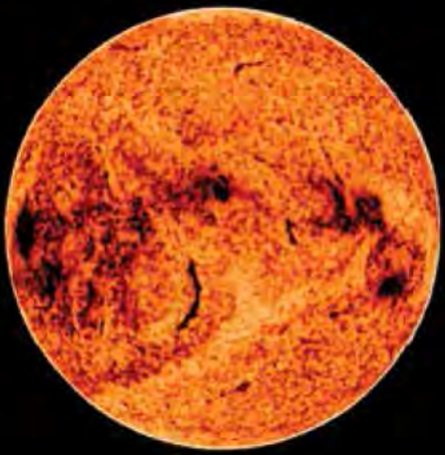
Electromagnetic radiation is a form of energy. It is given off by many different sources on Earth and throughout the universe. However, most of the electromagnetic radiation that reaches Earth comes from the Sun. The images shown here are all of the Sun. They are made by different telescopes, each of which detects a different type of electromagnetic radiation. Some types of electromagnetic radiation given off by the Sun are harmful to living things, including you. Other types are essential to the survival of life on Earth.

Key Concepts

- Electromagnetic radiation is an important part of your world.
- Sources of electromagnetic radiation are all around you.
- Electromagnetic radiation enhances how we sense our world.

Curricular Competencies

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest
- Co-operatively design projects
- Identify a question to answer or a problem to solve through scientific inquiry
- Consider social, ethical, and environmental implications of the findings



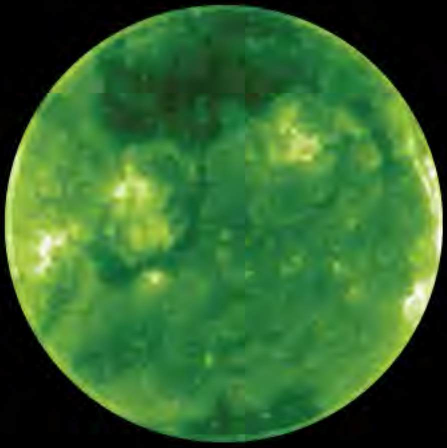
Infrared telescope

Optical telescope

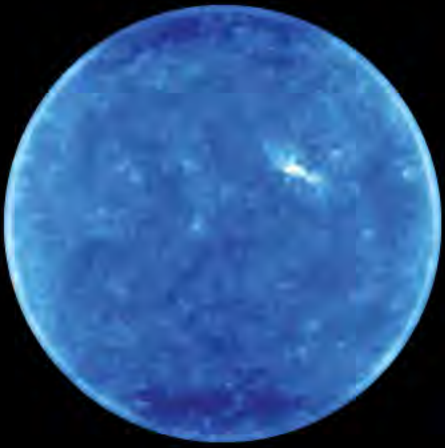
Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Visible light is only one type of electromagnetic radiation given off by the Sun. What other types have you heard of? How are they used? How do they affect your life?
2. **Communicating** Electromagnetic radiation is a form of energy. Use a graphic organizer to review what you already know about energy.
3. **Questioning and Predicting** Earth is knocked out of its orbit! It reads like the storyline of a science fiction movie, but imagine if this happened. Earth travels farther and farther from the Sun until the Sun is just a pinprick of light in a dark sky. What changes would take place on Earth if it no longer received the Sun's energy? Brainstorm as many ways as you can think of.



Ultraviolet telescope



X-ray telescope

Key Terms

There is one key term that is highlighted in bold type in this Topic:

- electromagnetic radiation

Flip through the pages of this Topic to find this term. Add it to your class Word Wall along with its meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Electromagnetic radiation is an important part of your world.

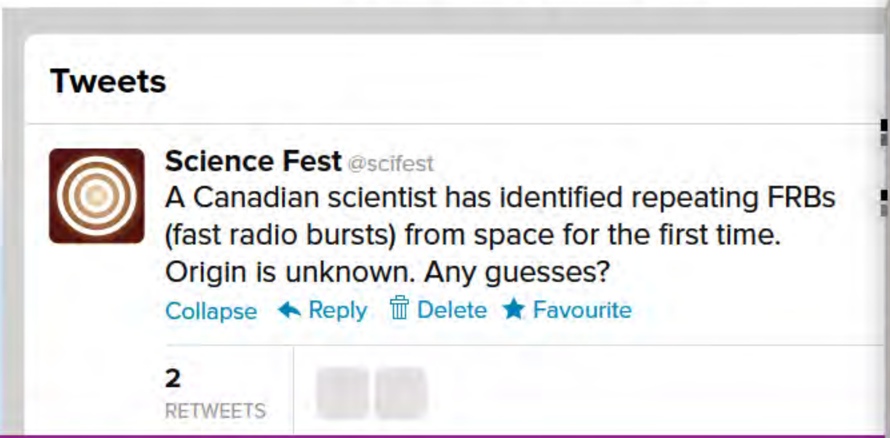
Activity

Electromagnetic Radiation on Prime Time

Congratulations! Your production team has scored a job to produce a two minute science segment on a local news show. Your segment is called "Electromagnetic Radiation in Your World." It will feature one way that electromagnetic radiation is making headlines. You can research one of the ideas on these pages, or you can find another story that interests you. The format is up to you. Working with your team members, create a script to fill your air time.

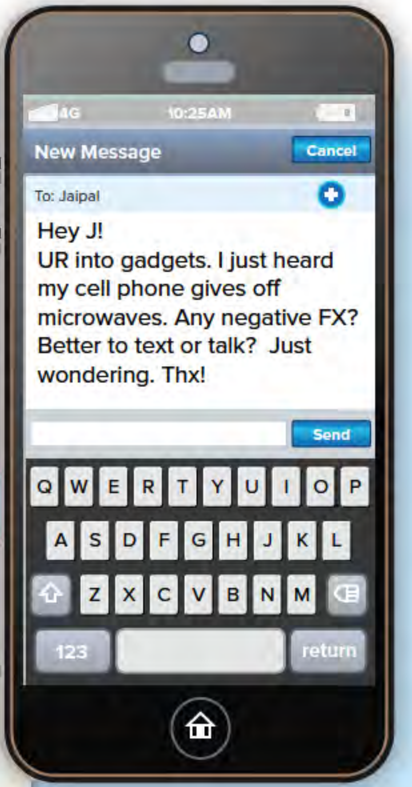
As shown in Figure 3.1, **electromagnetic radiation** shapes your world. Without it, there would be no cell phones, television, wireless Internet, or even life on Earth. Scientists have defined seven different types of electromagnetic radiation. These are radio wave, microwave, infrared, visible light, ultraviolet, X-ray, and gamma-ray radiation. Each type has expanded human ability or discovery in some way.

Figure 3.1 Electromagnetic radiation is often discussed online and covered by the news.



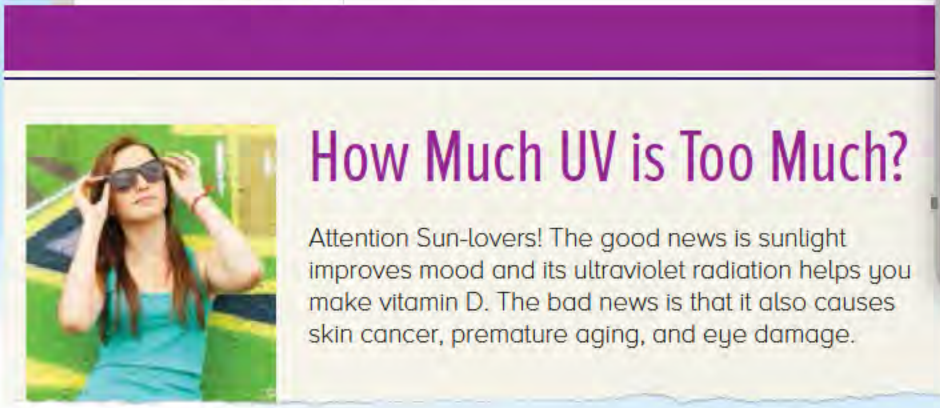
Tweets

Science Fest @scifest
A Canadian scientist has identified repeating FRBs (fast radio bursts) from space for the first time. Origin is unknown. Any guesses?



To: Jaipal

Hey J!
UR into gadgets. I just heard my cell phone gives off microwaves. Any negative FX? Better to text or talk? Just wondering. Thx!



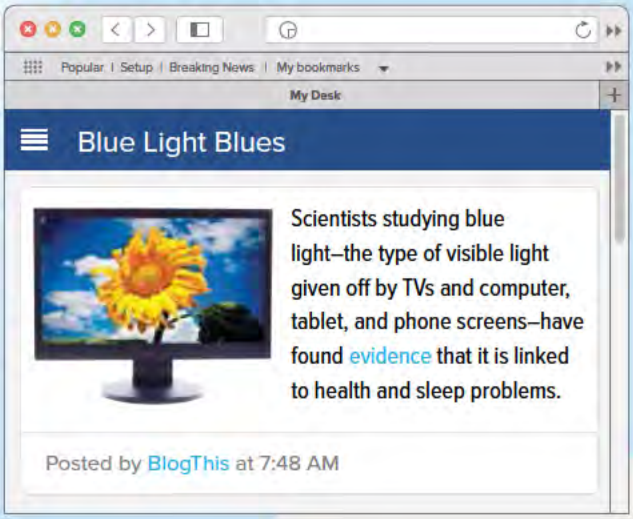
How Much UV is Too Much?

Attention Sun-lovers! The good news is sunlight improves mood and its ultraviolet radiation helps you make vitamin D. The bad news is that it also causes skin cancer, premature aging, and eye damage.

Dig This

X-Rays Solve Mystery

Archaeologists studying First Nations artifacts at the Sunshine Coast Museum have dated some to be over 5000 years old. X-ray technology has uncovered other information, too. A technique called X-ray fluorescence has helped archaeologists determine where the stone came from originally.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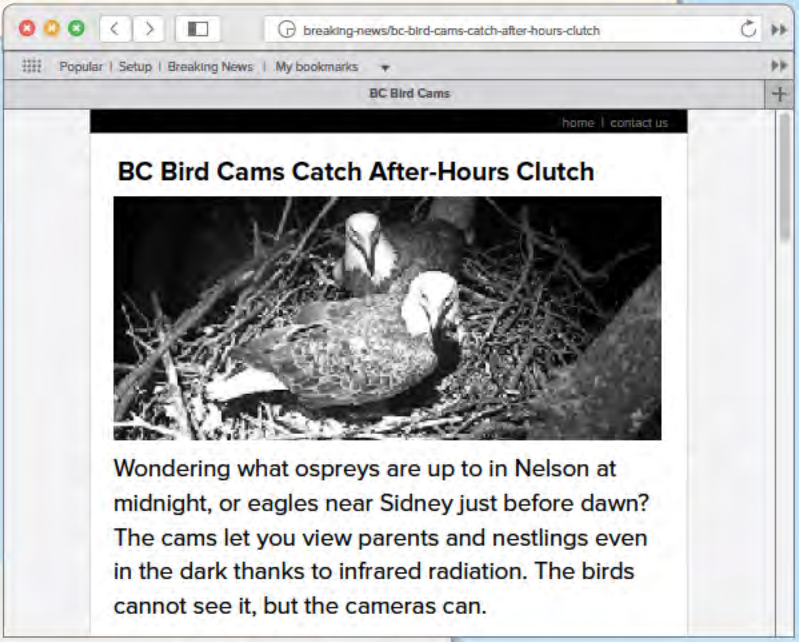
Blue Light Blues

Scientists studying blue light—the type of visible light given off by TVs and computer, tablet, and phone screens—have found evidence that it is linked to health and sleep problems.

Posted by BlogThis at 7:48 AM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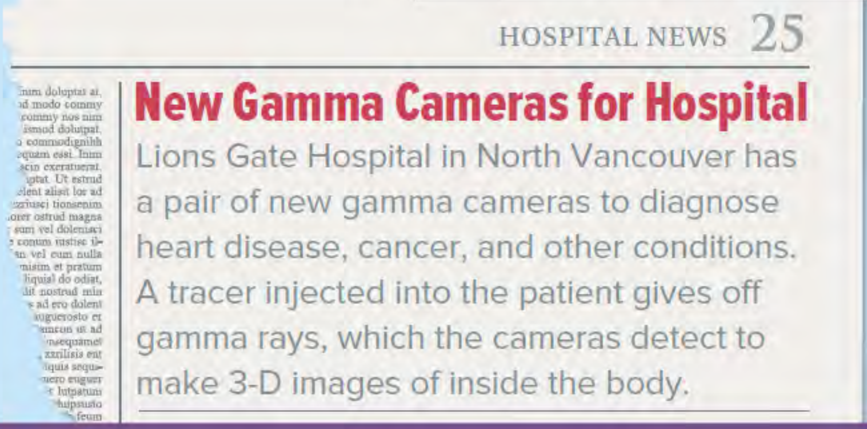
BC Bird Cams Catch After-Hours Clutch

Wondering what ospreys are up to in Nelson at midnight, or eagles near Sidney just before dawn? The cams let you view parents and nestlings even in the dark thanks to infrared radiation. The birds cannot see it, but the cameras can.



HOSPITAL NEWS 25

New Gamma Cameras for Hospital

Lions Gate Hospital in North Vancouver has a pair of new gamma cameras to diagnose heart disease, cancer, and other conditions. A tracer injected into the patient gives off gamma rays, which the cameras detect to make 3-D images of inside the body.

Before you leave this page . . .

1. Why do you think sunglasses have special lenses that filter out ultraviolet radiation?
2. Why might you want to limit the amount of time you spend in front of an electronic screen at night?

CONCEPT 2

Sources of electromagnetic radiation are all around you.

Activity

Electromagnetic Radiation Inventory

A lot of things you are familiar with give off electromagnetic radiation. As a class, brainstorm as many as you can. Then answer the questions below.

1. Which sources can be found in your home or school? in your community or region?
2. What other questions or concerns do you have about sources of electromagnetic radiation? Discuss these as a class.

Now that you have a better understanding of how electromagnetic radiation shapes your world, where do you think it comes from? There are many different sources of electromagnetic radiation. Some sources are familiar, like cell phones and light bulbs. Others, like X-ray tubes, may be unfamiliar. Some sources are artificial, while others are natural, including living organisms. Figure 3.2 explores several of these sources. You may be surprised to learn that even you are a source of electromagnetic radiation.

As you read about these sources, keep in mind that electromagnetic radiation is energy. That means it is neither created nor destroyed. Instead, it is transferred from one object to another or transformed into another kind of energy.

Figure 3.2 Some sources of electromagnetic radiation.

The Sun: A Source of All Types of Electromagnetic Radiation

The Sun gives off all types of electromagnetic radiation. The energy carried by this radiation is produced by nuclear fusion. During fusion, hydrogen nuclei collide and combine to form helium. Fusion releases an enormous amount of energy. How enormous? When 1 g of hydrogen atoms fuses, the reaction releases 65 billion kJ of energy—the amount of energy in over 50 000 pieces of pizza. More than 500 trillion grams of hydrogen fuse in the Sun every second. The incredible amount of energy released by the Sun supports life on Earth.

Chemical Reactions in Living Organisms: A Source of Visible Light

Chemical reactions can give off visible light. Some of these reactions occur in living organisms. The female anglerfish shown here lives deep in the ocean where sunlight cannot reach. It has a lure that gives off visible light to attract its prey (fish it eats). The lure dangles from a spine over the anglerfish's head. Bacteria living in the lure produce the light.

Telecommunications: A Source of Microwaves and Radio Waves

Your cell phone is a source of microwaves. The microwaves carry the information you put into the phone, whether speaking or texting, to a nearby cell phone tower. Wires then carry the information farther. If the information is going to another cell phone, it travels to the tower nearest that cell phone. The tower creates microwaves that carry the information to the other phone.

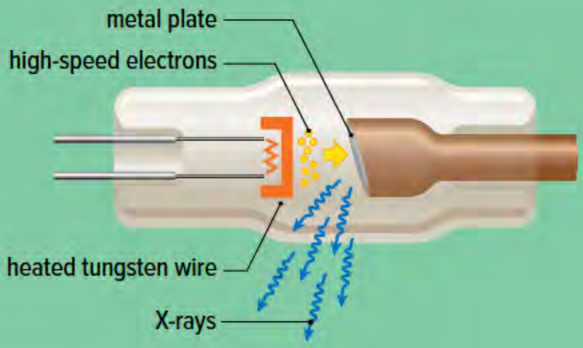
Commercial radio stations generate radio waves to send signals that radio receivers convert into sound. Communication systems used by police, fire, and emergency workers also generate radio waves. They use them for on-the-job communication.

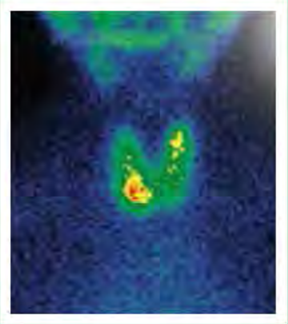
Heated Materials: A Source of Visible Light and Infrared Radiation

All objects, including you, give off infrared radiation. As an object gets hotter, it gives off more infrared radiation. You sense this energy as heat. If objects are very hot, they can give off visible light as well. For example, a wood fire, a candle flame, and a hot element on a stovetop give off light. Infrared radiation and light are also given off by light bulbs. For example, halogen bulbs have a thin tungsten wire enclosed in quartz. When the bulb is turned on, the tungsten gets very hot and gives off light. The bulbs are filled with halogen gas, which allows them to become very hot without burning out. Halogen bulbs are often used in high-intensity desk lamps.

X-ray Tubes: A Source of X-rays

X-rays are produced by a change in the speed of very fast-moving electrons. In an X-ray tube, high-speed electrons are released from a super-heated tungsten wire. The electrons then collide with a metal surface that stops them suddenly. This sudden change in speed generates X-rays, which can be used to create images of teeth or bones.





Radioisotopes: A Source of Gamma Rays

Gamma rays are produced by unstable nuclei of certain atoms. Atoms with unstable nuclei are called *radioisotopes*. Radioisotopes have too much energy. To become stable, they give off energy in different forms, including gamma rays.

Iodine-131 is a radioisotope that gives off gamma rays. It is used to treat thyroid cancer. When a cancer patient ingests (swallows) iodine-131, nearly all of it will go to the thyroid gland and kill the cancer cells. It will also kill some healthy cells, but this usually does not harm the person.

Radioactive iodine can also be used to study body functions. The gamma camera image on the left shows an overactive thyroid gland that was injected with radioactive iodine. Part of the gland looks brighter and larger. It has taken up more iodine, so the camera detects more gamma rays from that area.

Extending the Connections

The X-Ray Files

Many sources of electromagnetic radiation are truly out of this world!

1. Carry out research to find out more about extraterrestrial sources of electromagnetic radiation. (Extraterrestrial refers to anything that is beyond Earth.)
2. Choose one that interests you. Do more research to find the following information:
   - a description of the source
   - what type(s) of electromagnetic radiation the source gives off
   - how we measure or detect the electromagnetic radiation
   - one question you have about the source and the answer you found to it
   - an image of the source, if available
3. Use your findings to create a file about the source. Share your file with the class.

Before you leave this page . . .

1. What type or types of electromagnetic radiation are given off by the following sources?
   a) a halogen light bulb
   b) the Sun
   c) iodine-131
   d) you
2. Identify three sources of electromagnetic radiation that you interacted with this week.
3. A type of starfish uses electromagnetic radiation to warn predators that it does not taste good. What type of electromagnetic radiation is most likely given off by the starfish?

CONCEPT 3

Electromagnetic radiation enhances how we sense our world.

Activity

Electromagnetic Radiation Mnemonic

A mnemonic (neh-mon-ik) is a trick you can use to remember a list of names or words. For example, a mnemonic that can help you remember the seven different types of electromagnetic radiation is Radical Musicians In Vanderhoof Undo Xylophone Glue. Each word starts with the same letter as a type of electromagnetic radiation. Create your own mnemonic to help you remember the types of electromagnetic radiation.

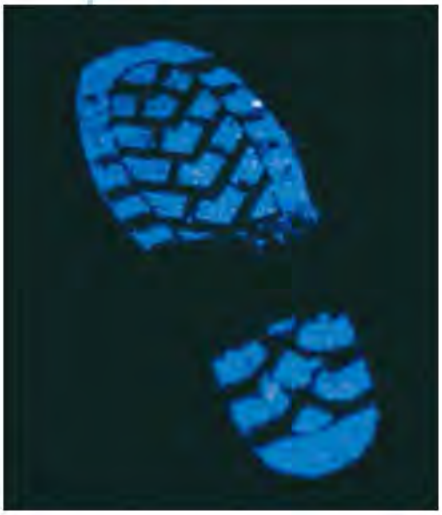
You are an electromagnetic radiation detector. Special cells in your skin sense infrared radiation and send a message to your brain that is interpreted as heat. Your eyes sense visible light to see brightness, objects, and colour. Modern technology has also opened the door to new ways for humans to sense the world, and beyond. Figures 3.3 to 3.6 explore just a few ways that law enforcement officers, medical professionals, and scientists use electromagnetic radiation and technology to "see" in a whole new way.

Solving Crimes

Electromagnetic radiation helps criminal investigators find evidence that is invisible to the unaided eye.

- Luminol is used to find traces of blood at a crime scene, as shown in Figure 3.3. This chemical undergoes a reaction with the iron in blood to give off visible light.
- Infrared photography creates images by sensing temperature differences. It is often used to find hidden evidence, such as weapons and other objects placed within walls.
- Investigators use X-ray, infrared, and ultraviolet radiation to uncover art forgeries. The radiation can help show an artist's unique brushstrokes, identify pigments and varnishes, and uncover other paintings an artist has painted over.

Figure 3.3 Luminol is sprayed at a crime scene to test for blood.



Connect to Investigation 3-A on page 200

Diagnosing Disease

Different kinds of electromagnetic radiation are used to identify medical problems.

- Radio waves and magnets work together in magnetic resonance imaging (MRI). The signals generated are used to create an image of the tissues being tested. Unhealthy tissues look different from healthy ones. An MRI image is shown in **Figure 3.4**.
- X-ray imaging is useful for diagnosing conditions like broken bones and cavities in teeth. X-rays are absorbed by bones and teeth but pass through most other body tissues.
- The B.C. Cancer Agency was the first to develop a handheld device that dentists and doctors can use to shine blue light into the mouth to detect cancer. The tongue normally glows under blue light or ultraviolet radiation, but cancerous tissue looks dark.

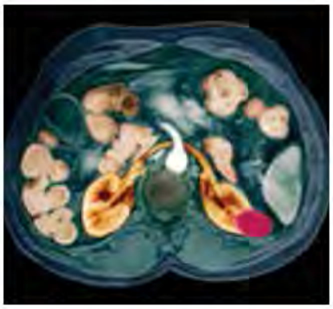


Figure 3.4 This MRI image shows a cross-section of a human abdomen. It has been coloured to help show the different organs.

Seeing Earth from Space

Electromagnetic radiation gives us a unique view of Earth. Satellites orbit high above Earth's surface. They use different types of electromagnetic radiation to gather information about our planet. This technology is called *remote sensing*.

- Weather satellites use reflected visible light and infrared radiation coming from Earth to obtain information about weather conditions (**Figure 3.5**). They can detect the location and movement of clouds and the amount of moisture in the atmosphere.
- LANDSAT is a satellite that measures visible light and infrared radiation coming from Earth's land surface to map it. Its images help with everything from monitoring loss of rain forests to finding near-shore shipwrecks.

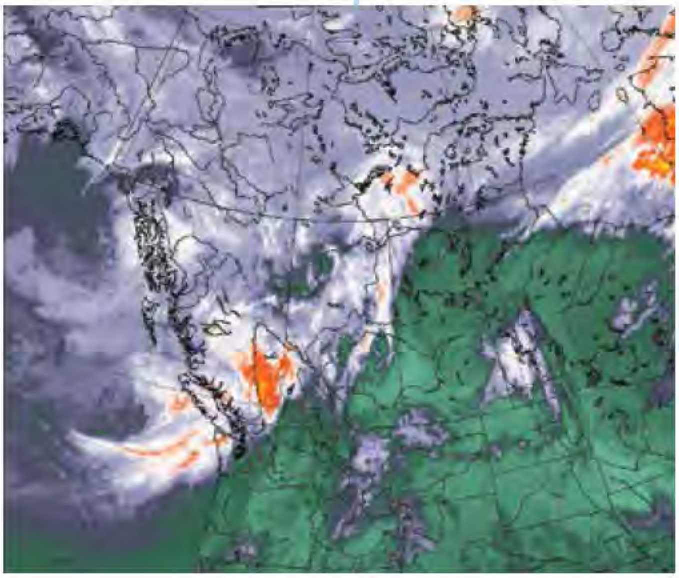


Figure 3.5 Satellite images of Earth help meteorologists forecast the weather.

Viewing the Universe

Electromagnetic radiation is being used to study the universe.

- The Hubble Space Telescope orbits Earth. It uses mirrors, one of which is over 2.4 m wide, to collect and focus visible light. *Focus* means to bring light to a point to form a clear image. The images produced are clearer than those from telescopes on Earth, because the blurring effect of Earth's atmosphere is avoided. Other instruments on the telescope sense ultraviolet and infrared radiation.
- The Very Large Array is the largest radio telescope on Earth. It consists of 27 receivers that work together to sense radio wave radiation from space. Other telescopes sense microwave, X-ray, and gamma ray radiation (**Figure 3.6**) to view the universe.

Figure 3.6 This image of a supernova (exploding star) combines data from telescopes sensing different kinds of electromagnetic radiation.

Activity

Electromagnetic Radiation Detective

Choose one of the problems below that interests you. Then carry out research as an electromagnetic radiation detective to solve it.

A. Crime Scene Challenge: You are a rookie detective in Fort St. John. You arrive at a crime scene with your supervisor. "The forensics team is here already. They're looking for body fluids with that ultraviolet light," says your supervisor. "Can you tell me which body fluids ultraviolet radiation can detect and how it detects them?" How do you respond?

B. Diagnosing Patient X: You are a student doctor in Victoria. You suspect that one of your patients has poor circulation in his hand. The senior doctor recommends a type of medical image called a thermogram. "Can you tell me how medical thermography works and what sort of electromagnetic radiation it uses?" the senior doctor asks. "What will the thermogram look like if the hand has poor circulation?" How do you respond? (Hint: A hand with poor circulation is cooler than a hand with normal circulation.)

Before you leave this page . . .

1. Describe how you are an electromagnetic radiation detector.
2. Use the information in this Concept to create a scenario like the ones in the activity above. Exchange scenarios with another student and try to solve the one you receive.

Connect to Investigation 3-B on page 201

AT ISSUE

How Can a Solar Superstorm Affect Earth?

What's the Issue?

AUGUST 28, 1859

On the night of Sunday, August 28, a mysterious event shut down telegraph communications across much of the world. (Telegraph machines once sent Morse code messages along telegraph lines linking different stations.) In Pittsburgh, Pennsylvania, the telegraph manager saw streams of fire that could not have been produced by the machines' batteries. Equipment became so hot that it couldn't be touched. Auroras, which mainly occur in the far north, were visible as far south as the Caribbean. Magnetic compasses went haywire. Instruments recording Earth's magnetic field recorded that the planet's magnetism had gone off the chart. The cause? A solar superstorm was raging on the Sun's surface. It lasted for six days.

July 2012

Technology has advanced in leaps and bounds since 1859. In 2012, the largest solar storm in recorded history occurred. Its harmful electromagnetic radiation, charged solar particles, and clouds of solar atmospheric material just narrowly missed Earth. Such a storm would have interfered with radio signals, affecting aircraft communications and GPS satellites. Scientists believe it would have shut down telecommunications and power grids around the world. The damage could have taken years to fix. If the storm had struck just one week earlier, Earth would have been directly in its path.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Find out how the amount of electromagnetic radiation reaching Earth can change during a solar storm and how this change can affect modern technology on Earth.
2. Find out what scientists and governments are doing to protect us from the effects of solar superstorms. How effective do you think their efforts will be?
3. Do you think more funding should be given to scientists who study solar storms and their effects? Why or why not?

SCIENCE AT WORK

Focus on Physics

What kinds of jobs are there that involve electromagnetic radiation?

Solar Electric Contractor

Alarm System Technician

Medical Imaging Technician

Laser Aesthetician

Photographer

Lighting Technician

From Ballet B.C. to your favourite indie band, lighting technicians use light and colour to bring stage performances alive, often in unexpected ways.

Air Traffic Controller

Air traffic controllers are responsible for thousands of lives each day. They rely on a clear head and technology based on electromagnetic radiation.

Astronomer

Feel like exploring new horizons? There are endless mysteries beyond our solar system that astronomers and the technologies they use can shed light on.

Questions

1. What other jobs and careers do you know or can you think of that involve electromagnetic radiation?
2. Research a job or career related to Unit 3 that interests you. What attracts you to it? What kinds of things do you have to know, do, and understand for this job or career?

TAKE a Stand

Make a Difference

Evaluate Cell Phone Safety

Microwave towers have sprung up across the country to accommodate the tens of millions of Canadian cell phone users. Health Canada publishes guidelines for safe exposure to microwave radiation from cell phone and other wireless communication signals (wi-fi). However, not everyone agrees with these guidelines. In 2015, *The Canadian Medical Association Journal* (CMAJ) published its concerns over Health Canada's guidelines. CMAJ interviewed many experts in the field who believe that allowable levels of microwave radiation in homes, schools, and workplaces are "a disaster to public health."

Evaluate and Communicate

1. Carry out research to find out more about the effects of cell phone and wi-fi microwave radiation on human health.
   - **a)** Explain how you assessed your sources for accuracy and reliability. (How did you know your sources were correctly representing information?)
   - **b)** Explain where you stand on this issue. Use your research to support your opinion.
   - **c)** Create a plan to share your research findings with other teens.
2. Find out more about Health Canada's guidelines.
   - **a)** Take a survey of a group of your choice, such as your friends or members of your community. Do they know about the guidelines? Do they follow them?
   - **b)** Summarize the results of your survey and discuss them as a class.

Check Your Understanding of **Topic 3.1**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Identify two natural sources of electromagnetic radiation and two artificial (human-made) sources of electromagnetic radiation. PA

2. Describe two ways in which electromagnetic radiation helps to carry out a task. PA

3. Describe two ways in which electromagnetic radiation can cause harm to living things. PA

4. Your eyes can sense light, and your skin can sense infrared. Describe a way that technology allows you to sense another type of electromagnetic radiation. PA AI

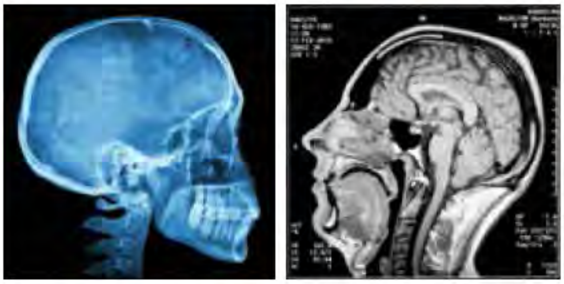
5. A criminal investigator testifies in court that traces of blood were found at the scene of a crime, even after the suspect tried to clean it up. Describe a technique the investigator could have used to find the evidence. PA AI

6. The Vancouver Art Gallery has been donated a previously unknown painting by B.C. artist Emily Carr. The donor claimed that the painting was made in 1929. As the curator, you are concerned that it may be a forgery. How could electromagnetic radiation be used to find out if it is a fake? PA AI

7. A weather forecast indicates that extremely heavy rainfall is approaching Port Alberni. The storm is expected to arrive within 24 hours. Describe the role electromagnetic radiation might have played in forecasting these weather conditions. PA AI

Connecting Ideas

8. These two images were made using electromagnetic radiation. PA E AI



   a) State the type of radiation you think was used to make each image. Justify your response.
   b) Which image do you think would give a doctor more information? Explain your reasoning.
   c) Why might a doctor choose to use the imaging technology that produces a less detailed view?

Making New Connections

9. Electromagnetic radiation has a huge impact on our ability to communicate. QP PA E AI C
   a) Describe three ways in which electromagnetic radiation helps us communicate.
   b) Explain how communications technology affects our ability to share knowledge, ideas, and feelings with people locally and globally.
   c) What, if any, responsibility do we have to use our ability for rapid communication wisely? What can happen when we don't?

INVESTIGATION

3-A

STRUCTURED INQUIRY AND GUIDED INQUIRY

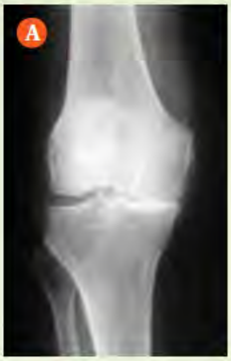
Exploring Medical Imaging Technologies

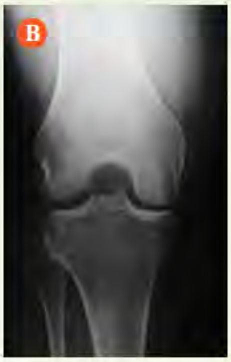
Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)





PART A: USING IMAGING TECHNOLOGY—STRUCTURED INQUIRY

Question

How can X-ray images be used to diagnose and treat medical problems?

Procedure

1. On an X-ray image, bone appears white, air appears black, and other structures appear in shades of grey. The images in A and B are from different patients.
2. Which image shows damage? What might have caused it?

Process and Analyze

1. How could X-ray images help a doctor treat a patient?
2. How could X-ray images help a doctor assess the effectiveness of the treatment?

PART B: ASSESSING IMAGING TECHNOLOGY—GUIDED INQUIRY

Question

How is imaging beneficial and harmful?

Procedure

1. Choose a medical imaging technology that uses electromagnetic radiation.
2. Find out how the imaging technology can help patients.
3. Find out how the radiation it uses can be harmful.

Evaluate and Communicate

1. Use a medium of your choice to communicate what you learned to patients.

INVESTIGATION

3-B

OPEN INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

Electromagnetic Radiation in Your Community

Electromagnetic radiation is a part of your community. It can play an everyday role, such as in telecommunications or simple Sun exposure. It may have a more unique application, such as a solar farm or space observatory.

Question

You will determine your own question to investigate. See step 3 of the Procedure.

Procedure

1. Find an example of how electromagnetic radiation is a part of your community.
2. Write out any questions you have about the example. Use the 5 W's (who; what; when; where; why) to help you brainstorm questions.
3. Decide which questions you will investigate, and plan how you will answer them.
4. Get your teacher to approve your plan.
5. Carry out your plan.

Evaluate and Communicate

1. How can you assess the reliability of the sources you are using in your research?
2. Create a plan to share what you have learned with your community. Keep in mind that your community includes people of different ages and backgrounds. How can you reach the most people in your community? If your teacher agrees, carry out your plan.

TOPIC
3.2

How can models explain the properties of electromagnetic radiation?

Key Concepts

- Visible light can be used to model all types of electromagnetic radiation.
- The ray model of light explains that light travels in straight lines.
- The wave model of light explains that light has wave-like properties.
- The particle model of light explains that light has particle-like properties.

Curricular Competencies

- Demonstrate an understanding and appreciation of evidence
- Formulate "If... then..." hypotheses based on your questions
- Identify possible sources of error and suggest improvements to investigations
- Ensure that safety and ethical guidelines are followed in investigations

Models are useful tools in many areas of science. Scientists use models to represent ideas and concepts, and to understand them better. Models also help scientists generate hypotheses and plan experiments. Models can be helpful in everyday life as well. For instance, the game plan shown here is a type of model. Coaches use game plans like this to explain strategies they want to use in a game.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Demonstrate your understanding of what a model is. Share your explanations, and see if your class can reach a consensus on a definition.
2. **Questioning** Think of another scientific model you have learned about this year or in previous studies. How is it helpful to scientists? How can it be used to make predictions?
3. **Applying** How might models help scientists understand the properties of visible light and other types of electromagnetic radiation?

Key Terms

There are six key terms that are highlighted in bold type in this Topic:

- ray model of light
- wave model of light
- amplitude
- particle model of light
- wavelength
- frequency

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Visible light can be used to model all types of electromagnetic radiation.

Activity

What's In a Name?

In science, names often give you information about the things they describe. The term electromagnetic radiation combines three smaller words: electric, magnetic, and radiation.

1. Find definitions of these three words and record them.
2. Based on these definitions, describe three properties that you think electromagnetic radiation might have.

Figure 3.7 Visible light and other electromagnetic radiation from the Sun travels 150 million km to reach Earth. Much of its journey is through empty space. (The brighter object here is Earth. The smaller, paler speck is our Moon.)

Observations and experiments have helped scientists learn a lot about the properties of electromagnetic radiation. For instance, they know:

- It is invisible as it travels. (Visible light must interact with matter to become visible.)
- It involves the transfer of energy from one place to another.
- It can travel through empty space (Figure 3.7).
- It travels through empty space at the speed of light (3.00×10^8 m/s).
- It has both electrical and magnetic properties.

As you can see, the seven types of electromagnetic radiation have much in common. In fact, they are so alike that studying one type can tell you a lot about the others. Visible light is often used as a model to study other types of electromagnetic radiation. It is fairly easy and safe to study. It also becomes visible when it interacts with matter.

Before you leave this page . . .

1. Why is visible light used as a model for other types of electromagnetic radiation?
2. Explain one way that visible light is different from other types of electromagnetic radiation and one way it is similar to them.

CONCEPT 2

The ray model of light explains that light travels in straight lines.

Activity

Evidence That Light Travels in Straight Lines

The photo demonstrates that light travels in straight lines. Consider your own experiences with light. What evidence have you seen that light travels in straight lines? How could you demonstrate that it does?

Fernie-based band Shred Kelly in concert.

It has taken thousands of years for people all over the world to develop an understanding of light. For example, more than 2000 years ago, a Greek mathematician named Euclid suggested that light travels in straight lines. You can use this idea to understand how shadows like those in Figure 3.8 form.

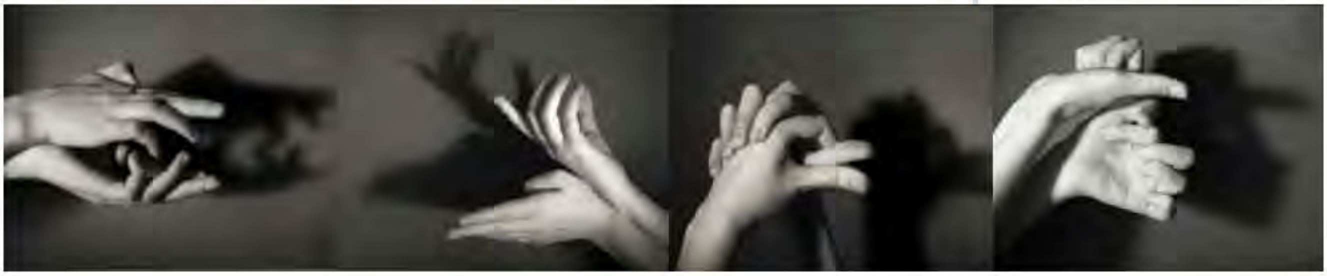
Understanding the Ray Model of Light

Look at Figure 3.8 again. In each photo, light from the light source cannot bend around the person's hands. The hands block the light and cast a sharp-edged shadow on the wall. This tells you that light must travel in straight lines. This idea is now referred to as the **ray model of light**. A *ray* is an arrow that is used to show the direction of the straight-line path of light.

Connect to Investigation 3-C on page 216

ray model of light the idea that light travels in straight lines

Figure 3.8 Hand shadow games like this were used by many First Peoples, not only for play, but also to develop various kinds of skills of benefit to the community. What kinds of skills could hand shadow games help someone develop?



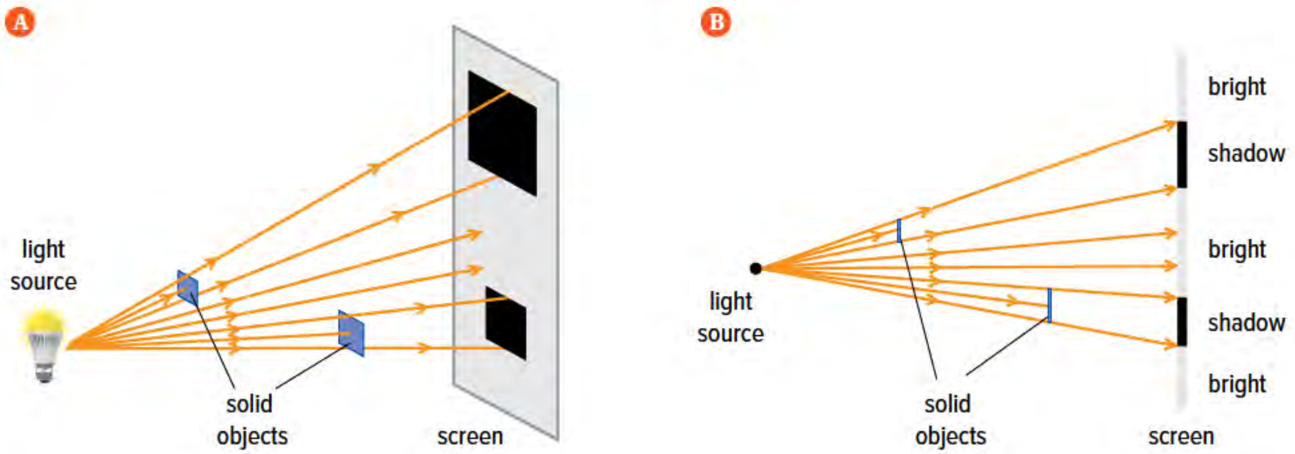

A
light source
solid objects
screen
B
bright
shadow
bright
shadow
bright
light source
solid objects
screen

Figure 3.9 A You can use ray diagrams to predict the location, size, and shape of shadows. Notice that the distance between an object and the light source affects the size of its shadow. B Ray diagrams are easier to draw if you view the object from the side. The light source can also be represented as a dot.

Using Ray Diagrams to Model Visible Light

Diagrams that involve rays are called *ray diagrams*. Ray diagrams are used to study and predict how light behaves. **Figure 3.9** shows how rays can be used to predict the location, size, and shape of shadows. The source of light is a small light bulb. It sends out rays in every direction. However, with a ray diagram, only a few of the rays travelling toward the objects need to be drawn.

Did you notice that the rays spread out in **Figure 3.9**? Light rays spread out as they travel from a light source. Because the rays spread out, light also gets dimmer as it travels. This effect is shown in **Figure 3.10**.

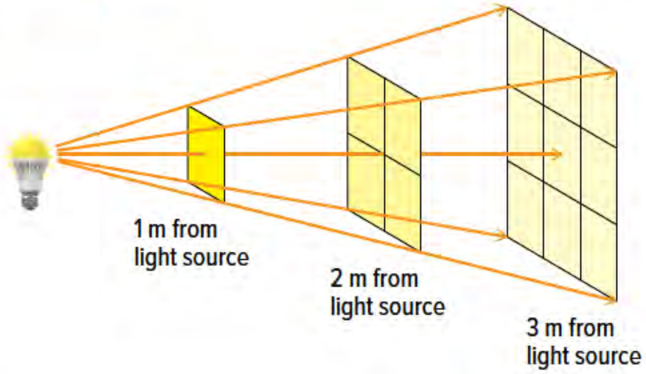

1 m from light source
2 m from light source
3 m from light source

Figure 3.10 Light rays spread out from a source and dim with distance. At 2 m from the light source, the light is $\frac{1}{4}$ as bright as it was at 1 m from the source. At 3 m, it is $\frac{1}{9}$ as bright.

Before you leave this page . . .

1. Like visible light, microwaves spread out from a source. How might this affect cell phone use?
2. In **Figure 3.9**, why does the smaller object cast the bigger shadow?

CONCEPT 3

The wave model of light explains that light has wave-like properties.

Activity

Can Waves Carry Energy?

You can observe that water waves carry energy when you see a photo like this. But how can you demonstrate that waves actually do carry energy? And does this apply to more than water waves? To start to investigate these questions, you will need a pan of water and a rope.

1. With a partner or in small groups, decide what is necessary to produce a wave using
   - a) water
   - b) rope
2. Is energy always needed to produce a wave? Explain your thinking.
3. How does a wave move energy from one place to another?
4. How can you change the size of the wave?
5. How can you change the speed of the wave?

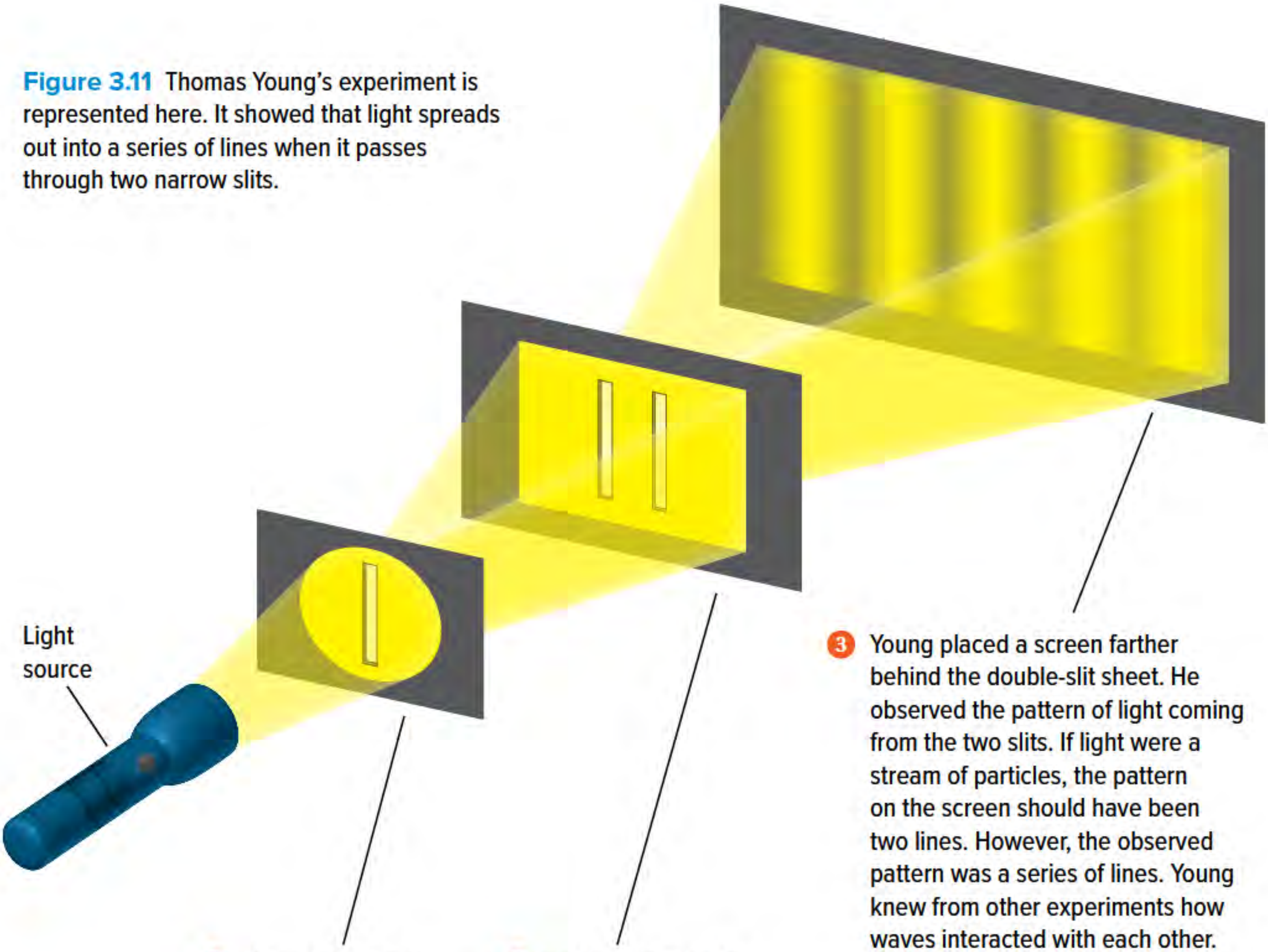
Observations of shadows enabled scientists to infer that light travels in a straight line. But there was still much about the properties of light to understand. Many scientists thought that light was made of streams of particles. The idea that light has particle-like properties is known as the **particle model of light**. A scientist named Isaac Newton was one of the first people to propose that light has these properties. However, he could not demonstrate this in an experiment.

As other scientists continued to study light, they realized that some properties could not be possible if light was simply a stream of particles. Some scientists argued that light has wave-like properties. In the early 1800s, a scientist named Thomas Young designed an experiment to test the hypothesis that light has the properties of a wave. His experiment supported the idea of a **wave model of light**. Young's experiment is explained in Figure 3.11 on the next page.

particle model of light the idea that light has particle-like properties

wave model of light the idea that light has wave-like properties

Figure 3.11 Thomas Young's experiment is represented here. It showed that light spreads out into a series of lines when it passes through two narrow slits.



① Young shone light through a single slit in a solid sheet.

② He then directed this light to two slits in another solid sheet.

③ Young placed a screen farther behind the double-slit sheet. He observed the pattern of light coming from the two slits. If light were a stream of particles, the pattern on the screen should have been two lines. However, the observed pattern was a series of lines. Young knew from other experiments how waves interacted with each other. The pattern of lines he observed could only be explained if light had wave-like properties.

Extending the Connections

How Do Waves Interact?

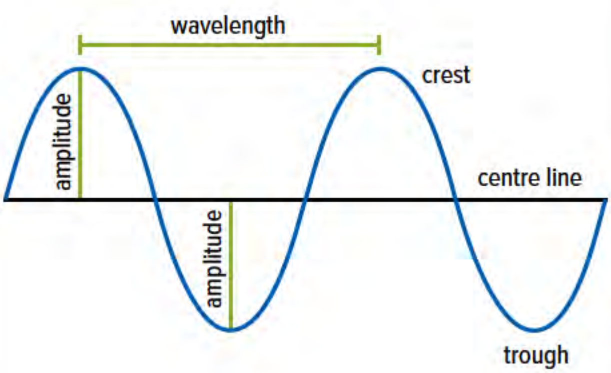
What do you think Thomas Young knew about waves that helped him interpret his experimental results? Investigate your own questions and ideas about waves. Find out what Young knew, and compare your own ideas to his.

Properties of Light Waves

Light waves have some things in common with water waves. Both types of waves move energy from one place to another. In water waves, the energy causes water molecules to vibrate up and down. This motion produces the shape shown in Figure 3.12. Scientists use the shape of a water wave to model light waves. Like a water wave, light waves have a wavelength. They also have amplitude and frequency. These terms are explained in Figure 3.12 and 3.13.

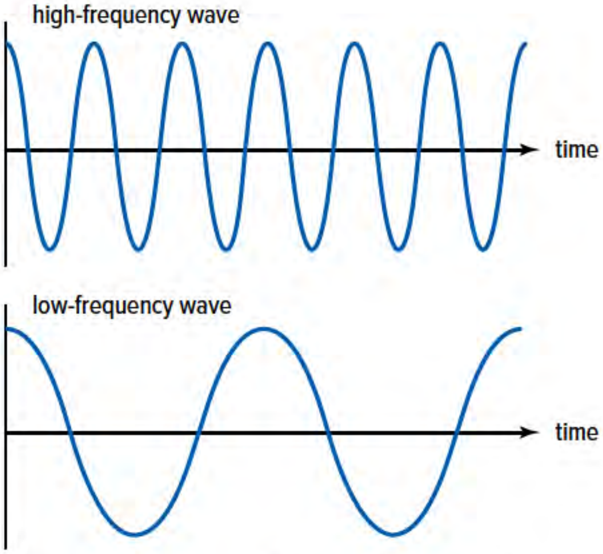
Connect to Investigation 3-D on page 217

Figure 3.12 This wave illustrates wavelength and amplitude.



The crest of a wave is the highest point, and the trough of a wave is the lowest point. The distance from the centre line to the crest is the same as from the centre line to the trough. **Wavelength** refers to the distance from one crest (or trough) of a wave to the next crest (or trough). **Amplitude** is the distance from the centre line to the crest or trough of the wave.

Figure 3.13 This wave illustrates frequency.



This diagram shows two waves with different frequencies. **Frequency** refers to the number of complete wavelengths that pass a point in one second as the wave goes by. As the wavelength decreases, the frequency increases. And as the wavelength increases, the frequency decreases.

Extending the Connections

Light Waves Are More Complicated Than Water Waves

Even though scientists use a water wave as a model for a light wave, light waves are more complicated. This is because light waves have electrical and magnetic properties. Find out how electromagnetic waves are different from the simpler model used for water waves.

wavelength the distance from one crest (or trough) of a wave to the next crest (or trough)

amplitude the distance from the centre line to the crest or trough of a wave

frequency the number of complete wavelengths that pass a point in one second as the wave goes by

Light, Wavelength, and Colour

Connect to Investigation 3-E on page 218

In the 1600s, Isaac Newton used a prism to separate visible light into the colours of the rainbow (**Figure 3.14**). He hypothesized that if light were a mixture of colours, the colours would recombine to form white light if they passed through another prism. He set up an experiment to test this idea and observed that they did. In this way, Newton was the first scientist to show that sunlight was actually a mixture of light of different colours.

The colours of light are actually different wavelengths of visible light. Together, they are referred to as the *visible light spectrum*. The colour red has the longest wavelength of visible light. Violet has the shortest.

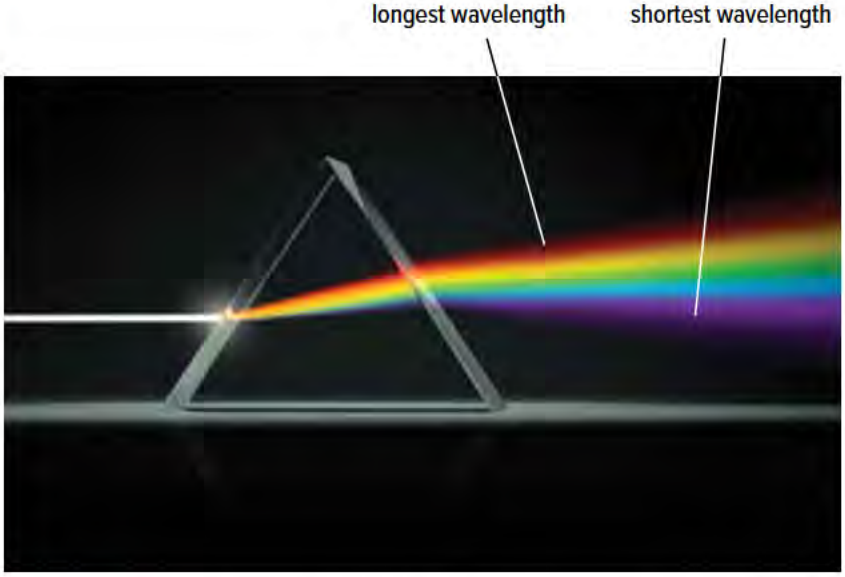


Figure 3.14 Newton separated visible light into colours. At the time, he did not know that the colours are actually different wavelengths of light. The colours of the spectrum fall in a certain order. You can remember the colours and their order using the mnemonic ROY G BIV. Use this figure to determine what each letter in the mnemonic stands for.

Before you leave this page . . .

1. Describe one way that a light wave is like a water wave. Describe one way that it is different.
2. One wave has a higher frequency than another wave. Which wave would have the longer wavelength? Explain your reasoning.

CONCEPT 4

The particle model of light explains that light has particle-like properties.

Activity

Thought Experiment

A thought experiment is an experiment that is carried out in your head.

1. Complete the thought experiment below before you read Concept 4.

   Your friend challenges you to try to make a bowling ball start rolling by rolling other balls toward it. What would happen in the following situations?

   a) You roll table-tennis balls toward the bowling ball. You can use as many table-tennis balls as you want. Can you make the bowling ball roll?

   b) Repeat the thought experiment with tennis balls. What will happen?

   c) You can choose any other type of ball you want. What type of ball would you choose to roll at the bowling ball to make it start rolling? Explain why you made the choice that you made.

2. Read Concept 4. Compare the results of your thought experiment with Figure 3.16. What part of your thought experiment is similar to the red light? What part of your thought experiment is similar to the blue light?

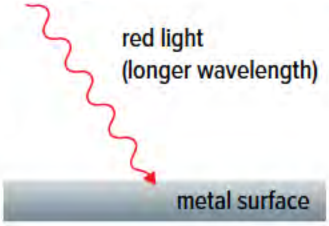
You might think Young's experiment convinced scientists that light (and every type of electromagnetic radiation) has the properties of a wave. But there was a property of light that the wave model could not explain: the photoelectric effect. Figure 3.15 describes this effect. Figure 3.16 on the next page gives Albert Einstein's explanation of why the effect occurs and why light has both wave-like and particle-like properties.

Figure 3.15 The Photoelectric Effect

This effect was first discovered by a scientist named Philipp Lenard. He shone different colours of light onto the surface of a certain metal and observed the following results:

Red Light: Electrons are *never* given off when energy from red light hits the metal.

- Electrons are not given off no matter how bright the red light is.
- Electrons are not given off no matter how long the red light shines on the metal.



Blue Light: Electrons are *always* given off when energy from blue light hits the metal.

- Electrons are always given off no matter how dim the blue light is.
- Electrons are always given off no matter how briefly the blue light shines on the metal.

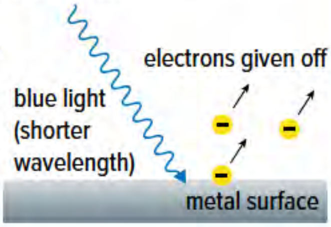


Figure 3.16 Einstein's Thought Experiment

Einstein realized that the wave model of light could not explain the photoelectric effect. If light interacts with the metal like a wave, waves of red light should eventually "pile up" enough energy to give off electrons. But this doesn't happen. So some other difference between red and blue light must cause the effect. Here is how Einstein reasoned.

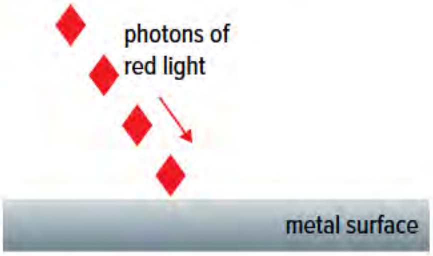
1. The photoelectric effect can only be explained if light acts like a particle when it interacts with matter.

Light does not interact with matter as a flowing stream, like water from a faucet.

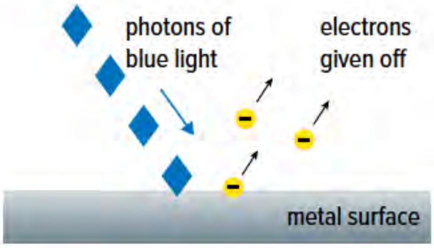
Light interacts with matter as packets or distinct particles, like water in ice cubes.

2. Einstein called the packets or particles of energy *photons*. Each photon must carry an exact amount of energy that is enough to make the metal give off electrons. Otherwise, nothing will happen when the photons strike the metal.

Red Light: Photons of red light *do not* carry enough energy to make the metal give off electrons.



Blue Light: Photons of blue light *do* carry enough energy to make the metal give off electrons.



3. Photons must carry more energy as the frequency of electromagnetic radiation increases and wavelength decreases.

Red Light: Red light has a lower frequency and a longer wavelength. Photons of red light carry less energy.

Blue Light: Blue light has a higher frequency and a shorter wavelength. Photons of blue light carry more energy.

In summary: Einstein realized that the best explanation for the photoelectric effect was that light acts like a particle when its energy is absorbed by an object. This particle, called a photon, acts a lot like a particle of matter.

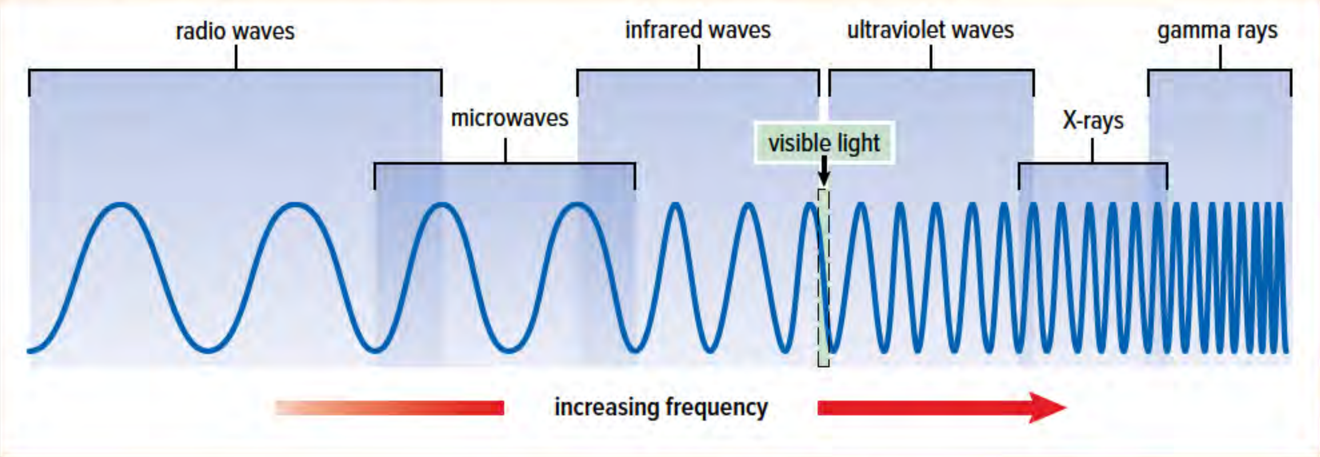
Before you leave this page . . .

1. Does light have the properties of a wave, a particle, or both? Explain your reasoning.
2. Scientists build on the work of other scientists. Explain how this is true of Einstein's explanation of the photoelectric effect.

AT ISSUE How can you model the electromagnetic spectrum?

What's the Issue?

Visible light is just one type of electromagnetic radiation, and all types of electromagnetic radiation have similar properties. This means that properties such as wavelength, frequency, and amplitude are properties of all types of electromagnetic radiation. The *electromagnetic spectrum* is a model that shows the range, or spectrum, of electromagnetic radiation in terms of wavelength. The spectrum begins with the radiation that has the longest wavelengths: radio waves. It ends with the shortest wavelengths: gamma rays.



Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

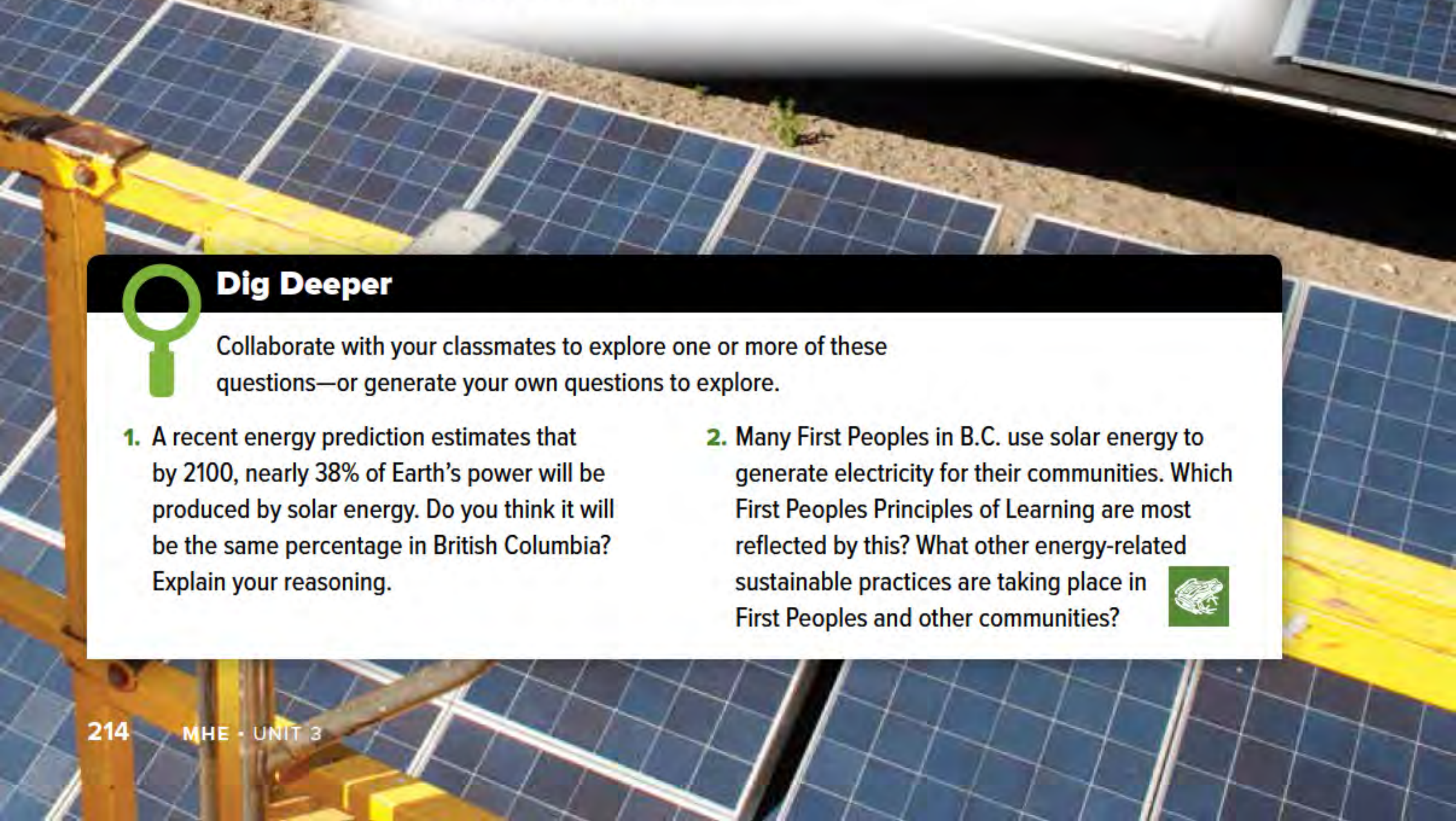
1. Use the diagram of the electromagnetic spectrum on this page as a starting point. How can you bring more meaning and understanding to it? For example:
   - **a)** How could you compare the sizes of wavelengths to familiar objects?
   - **b)** How could you add numerical or mathematical information?
   - **c)** How and where could you use colour to enhance your understanding of the electromagnetic spectrum?
   - **d)** How could you add examples of applications of electromagnetic radiation, such as modern communications technology?
2. Find out how different parts of the spectrum were discovered. (For instance, the discovery of infrared built on the work of Isaac Newton. The discovery of ultraviolet built on work that led to infrared. But how?)

AT ISSUE How Can Solar Power Projects Conserve Energy?

What's the Issue?

Chief Gordon Planes may just be one of the most innovative thinkers in B.C. He worked with the T'Sou-ke First Nation, located 45 minutes southwest of Victoria, to build what at the time was the largest photovoltaic project in B.C. Overall, the T'Sou-ke First Nation reduced its energy use by 75%. Planes's vision continues to lead the community toward energy conservation and self-sufficiency.

The photoelectric effect helps you understand how photovoltaic cells work. Electrons in the cells are trapped and need a certain amount of energy to escape to form an electric current. Photons in visible light from the Sun have just the right amount of energy. When the photons collide with the electrons, the energy frees the electrons and allows them to form a current. The current carries the energy to where it can be used. New materials are being developed that can also use photons of infrared and ultraviolet radiation to produce a current.



Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. A recent energy prediction estimates that by 2100, nearly 38% of Earth's power will be produced by solar energy. Do you think it will be the same percentage in British Columbia? Explain your reasoning.
2. Many First Peoples in B.C. use solar energy to generate electricity for their communities. Which First Peoples Principles of Learning are most reflected by this? What other energy-related sustainable practices are taking place in First Peoples and other communities?

Check Your Understanding of **Topic 3.2**

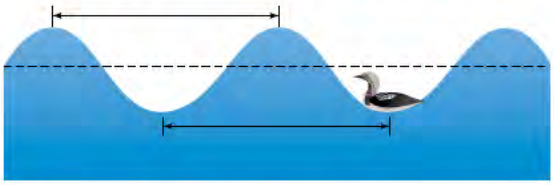
QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Why is it more useful or helpful to use visible light as a model for electromagnetic radiation, rather than X-rays or any other type? PA E

2. At 2 m from a light source, light is $\frac{1}{4}$ as bright as it was at 1 m from the source. Explain why this is the case. PA C

3. The diagram below shows a Pacific loon resting on water. Add labels to show your understanding of the following terms: wavelength, crest, trough. PA E AI C



4. Visible light travels through empty space at the speed of light (3.00×10^8 m/s). Would an astronaut in orbit around Earth see visible light from the Sun as it travels through outer space? Explain your reasoning. PA AI

5. Use a diagram to show how each model below explains at least one property of electromagnetic radiation. PA C
   - **a)** the ray model of light
   - **b)** the wave model of light
   - **c)** the particle model of light

6. Predict what a shadow would look like if light did not travel in a straight line. Justify your prediction. QP PA

Connecting Ideas

7. Einstein used a thought experiment to explain the photoelectric effect. In what ways is a thought experiment similar to and different from a hands-on experiment? What are the advantages and disadvantages of using thought experiments? E AI C

8. Create a comic strip showing a conversation that Young and Einstein might have had about the nature of light. PA C

9. Figure 3.14 showed what happens when a beam of visible light passes through a prism. However, this photo does not provide conclusive evidence that visible light is made up of different colours.
   - **a)** Explain why this is the case.
   - **b)** Describe how Newton demonstrated that visible light is made up of colours.

   PC E AI

Making New Connections

10. Sound is a different form of energy from electromagnetic radiation, but sound also has wave-like properties. QP PC AI
    - **a)** Predict how changes in wavelength, frequency, and amplitude affect sound. For example, imagine that you press a key on a piano keyboard. How would a change in frequency, wavelength, and amplitude change the sound?
    - **b)** Describe a plan for an investigation that you could conduct to test your prediction.

INVESTIGATION

3-C

STRUCTURED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Never shine a light directly into someone's eyes.
- Do not touch the bulb of the light source. It may be extremely hot.

What You Need

- light source
- books and boxes
- ruler
- pencil
- paper

Shadow City

Create a city skyline and explore the ray model of light by changing the size and shape of its shadow.

Question

How can you use shadows to demonstrate how light travels?

Procedure

1. In a small group, use books and boxes to create a city skyline. Place a light source about 50 cm in front of the skyline. Place a screen about 50 cm behind the skyline.
2. Measure the distance from the light source to the skyline, the distance from the skyline to the screen, and the height of the tallest "building" in the skyline. Record your measurements.
3. Draw a ray diagram showing your skyline, the light source, and the screen. Use Figure 3.9 as a guide. Because you are viewing your skyline from the side, you can draw it as a simple box that is as tall as your tallest building. The diagram should be to scale. For example, 1 mm on your drawing could represent 1 cm on your skyline.
4. Draw several more ray diagrams. Try to make your shadows taller, shorter, larger, or smaller.
5. Your teacher will turn off the overhead light. Turn on your light source. Take turns changing the height and size of the shadow.

Process and Analyze

1. a) Did your observations support your ray diagrams?
   b) If not, try to account for any differences.

INVESTIGATION

3-D

STRUCTURED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Applying and Innovating

Safety

- Do not release the spring when it is fully stretched or moving.
- The ends of the spring may be sharp.
- Keep the spring on the floor when making waves.

What You Need

- a coiled metal spring or skipping rope

Modelling Wavelength, Frequency, and Amplitude

Question

How can you model wavelength, frequency, and amplitude?

Procedure

1. Draw and label a diagram for each of the following:
   a) a high-amplitude wave and a low-amplitude wave
   b) a high-frequency wave and a low-frequency wave
   c) a short-wavelength wave and long-wavelength wave
2. Plan how you can use a rope or spring to model the six waves in step 1.
3. Carry out your plan.
4. See if you can make the following:
   a) a low-frequency, long-wavelength wave
   b) a low-frequency, low-amplitude wave
   c) a high-amplitude, short-wavelength wave
   d) a high-frequency, long-wavelength wave
5. Draw a diagram of each wave that you made in step 4.

Process and Analyze

1. What relationships did you discover among wavelength, frequency, and amplitude? For example, if frequency decreases, what happens to wavelength?

Apply and Innovate

2. What other materials could you use to produce waves? Design an investigation in which you use these waves to model frequency, wavelength, and amplitude.

INVESTIGATION

3-E

STRUCTURED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Processing and Analyzing
- Applying and Innovating

Safety

- Never look directly at the Sun. You may damage your eyes.
- Do not touch the bulb of any light source. It may be extremely hot.

What You Need

- spectroscope
- ruler
- coloured pencils

Seeing Through a Spectroscope

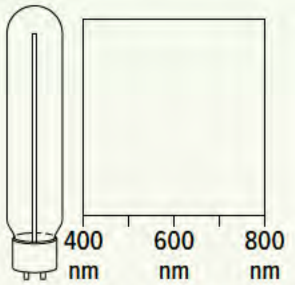
In this Investigation, you will observe different sources of light through a spectroscope.

Question

What property of a wave of visible light determines its colour?

Procedure

1. Make a hypothesis about what property of a wave of visible light determines its colour.
2. Your teacher will set up different light sources. Observe each one through the spectroscope. Draw your observations. If a pattern repeats, just draw one repetition.
3. Your teacher will give you several copies of the diagram on the right or ask you to copy it for each light source. Place the colours you saw through the spectroscope on the diagrams.



1 nm = 0.000 000 001 m

4. Use your answers to question 3 to estimate the wavelength for each colour of the visible light spectrum.

Process and Analyze

1. Did your observations in this experiment support your hypothesis? Why or why not?
2. How did light behave like a wave in this Investigation?
3. What sources of error might have occurred in this Investigation?

Apply and Innovate

4. Astronomers also use spectroscopes. Find out what a spectroscope can reveal about the stars.

INVESTIGATION

3-F

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- You will write your own safety guidelines.

What You Need

- ultraviolet-sensitive beads
- other materials depending on your experimental design

Exploring Ultraviolet Radiation

Ultraviolet-sensitive beads change colour when exposed to ultraviolet radiation. The colours become more intense when the beads are exposed to more UV radiation.

Question

See step 1 below to choose a question to investigate.

Procedure

1. Choose one of these questions to investigate with your group, or come up with your own.
   a) How effective are different materials at blocking ultraviolet radiation?
   b) How effective are different sunscreens at blocking ultraviolet radiation?
   c) How can you demonstrate the existence of ultraviolet radiation just beyond violet light in the visible light spectrum?
2. Write a hypothesis that answers your question.
3. Design an experiment to test your hypothesis. Identify the variables in your experiment. Include safety guidelines and a materials list.
4. Share your hypothesis and design in a feedback session with your teacher and classmates.
5. Carry out your experiment.

Process, Analyze, and Communicate

1. Write a report based on your experiment. Identify possible sources of error and suggest improvements to your experimental design.
2. Did your results support your hypothesis? Explain.

TOPIC 3.3

How does light behave when it encounters different materials and surfaces?

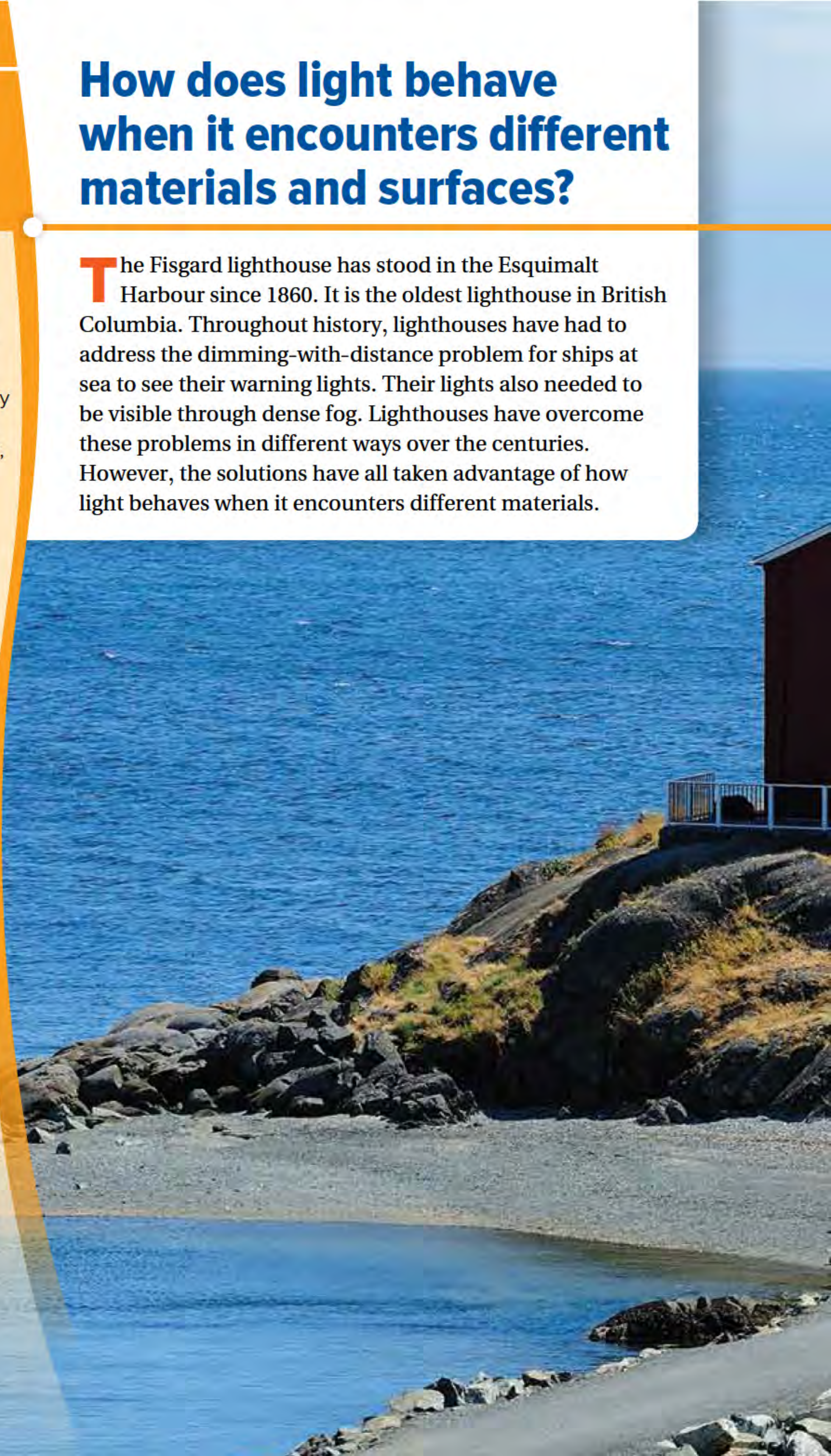
The Fisgard lighthouse has stood in the Esquimalt Harbour since 1860. It is the oldest lighthouse in British Columbia. Throughout history, lighthouses have had to address the dimming-with-distance problem for ships at sea to see their warning lights. Their lights also needed to be visible through dense fog. Lighthouses have overcome these problems in different ways over the centuries. However, the solutions have all taken advantage of how light behaves when it encounters different materials.

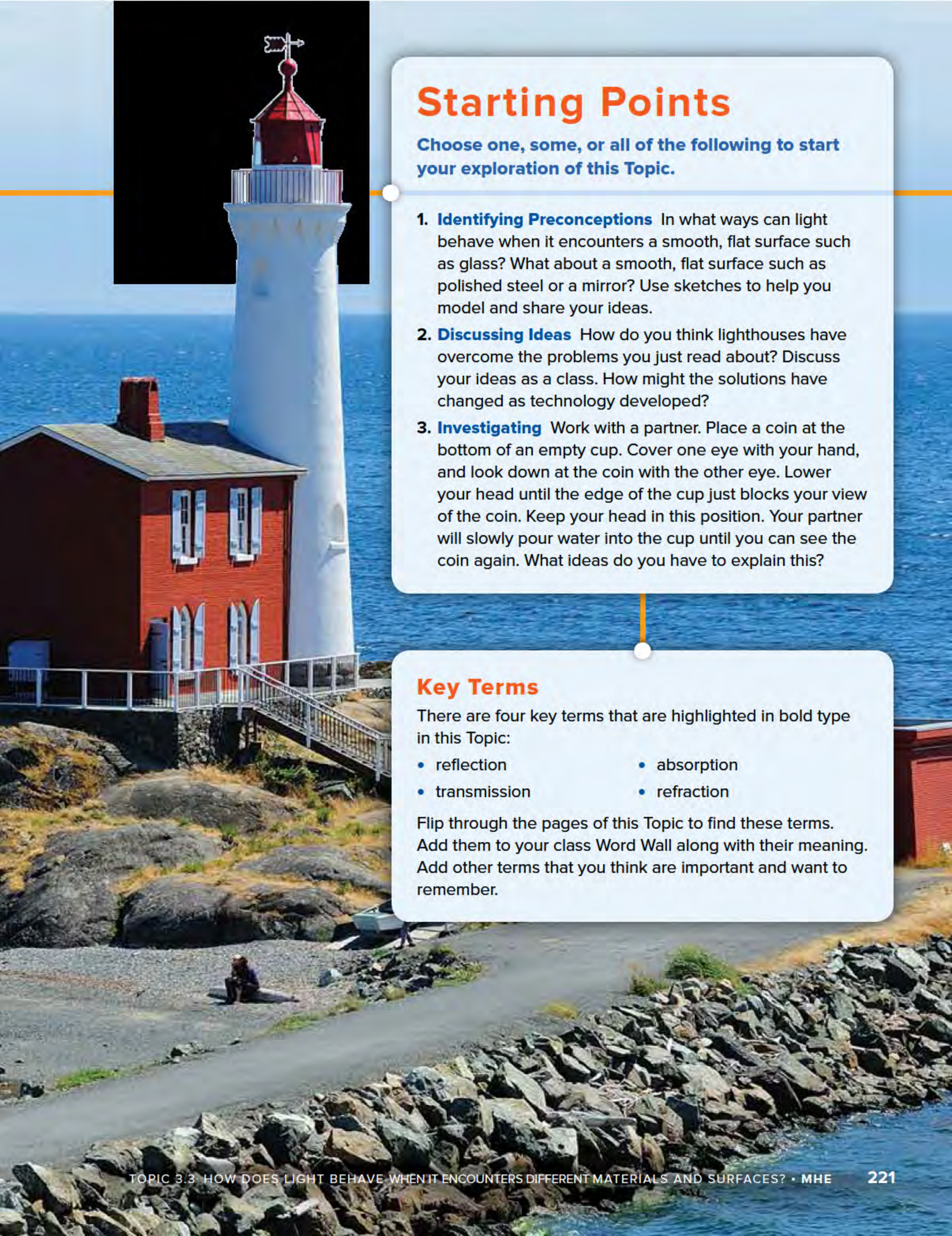
Key Concepts

- Light can be reflected, absorbed, transmitted, or refracted.
- Light behaves differently when it encounters transparent, translucent, or opaque materials.

Curricular Competencies

- Generate or introduce new or refined ideas while problem solving
- Make predictions about inquiry findings
- Express and reflect on a variety of experiences and perspectives of place
- Experience and interpret the local environment





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** In what ways can light behave when it encounters a smooth, flat surface such as glass? What about a smooth, flat surface such as polished steel or a mirror? Use sketches to help you model and share your ideas.
2. **Discussing Ideas** How do you think lighthouses have overcome the problems you just read about? Discuss your ideas as a class. How might the solutions have changed as technology developed?
3. **Investigating** Work with a partner. Place a coin at the bottom of an empty cup. Cover one eye with your hand, and look down at the coin with the other eye. Lower your head until the edge of the cup just blocks your view of the coin. Keep your head in this position. Your partner will slowly pour water into the cup until you can see the coin again. What ideas do you have to explain this?

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- reflection
- transmission
- absorption
- refraction

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Light can be reflected, absorbed, transmitted, or refracted.

reflection the process in which light "bounces off" the surface of an object and travels in another direction

Light interacts with different materials and surfaces in different ways. Light may reflect, be absorbed, be transmitted, or refract.

Reflection: Light Bounces Off

When light strikes an object, it often just reflects from its surface. **Reflection** is the process in which light "bounces off" a surface and changes direction. There are two different types of reflection.

Reflection Off an Extremely Smooth Surface

Every time you look in a mirror, you see light reflect off an extremely smooth surface. This produces a clear image (a likeness) of you and your surroundings. This type of reflection also occurs on the surface of a very still body of water, like the one in Figure 3.17. You can also observe it on some polished surfaces, such as glass or metal. When such a surface reflects light, the pattern of reflected rays is very similar to the pattern of the incoming rays. This similarity is what lets you see an image when the light reaches your eyes (Figure 3.18).

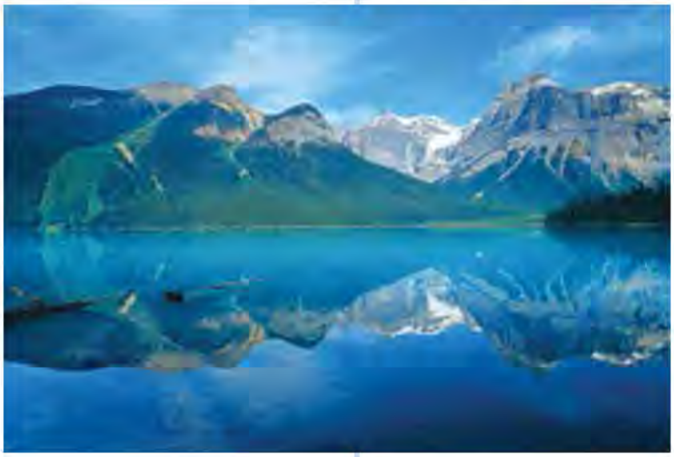


Figure 3.17 In this photograph, Emerald Lake in Yoho National Park has an extremely smooth surface in which an image is visible.

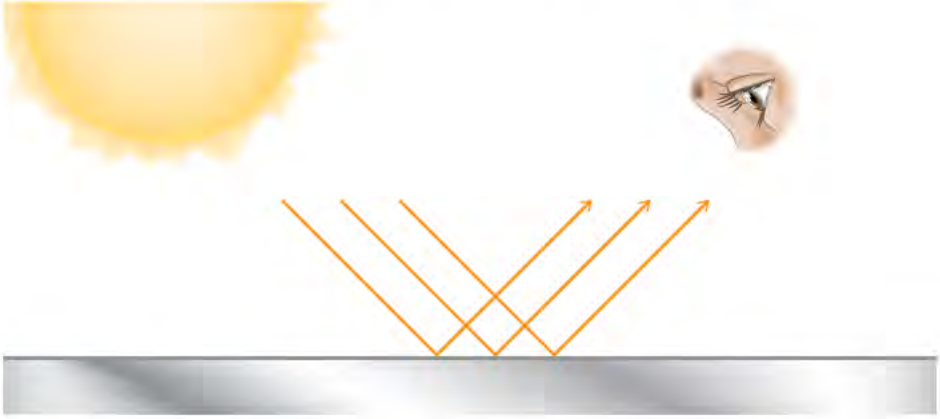


Figure 3.18 Light rays reflecting off a smooth, mirror-like surface have a pattern that is very similar to that of the incoming rays.

Reflection Off a Rough Surface

Light can also reflect off a rough surface, such as a piece of paper. This type of reflection does not produce an image. However, it does make objects visible. Figure 3.19A shows how this works. Notice how the reflected rays go in many different directions. The pattern of the reflected rays is no longer similar to the pattern of the incoming rays, so no image appears on the paper. However, some reflected rays do reach your eyes. These make the paper visible.

Why do the rays reflect in all directions? Paper might look smooth to the unaided eye, but Figure 3.19B shows otherwise. Under a microscope, the paper's surface looks rough and uneven. When light hits this surface, it scatters in many different directions.

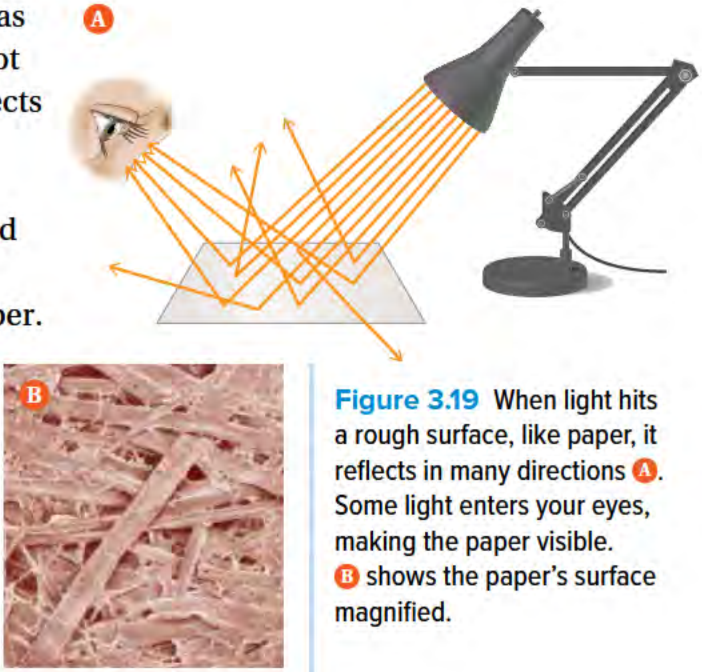


Figure 3.19 When light hits a rough surface, like paper, it reflects in many directions Ⓐ. Some light enters your eyes, making the paper visible. Ⓑ shows the paper's surface magnified.

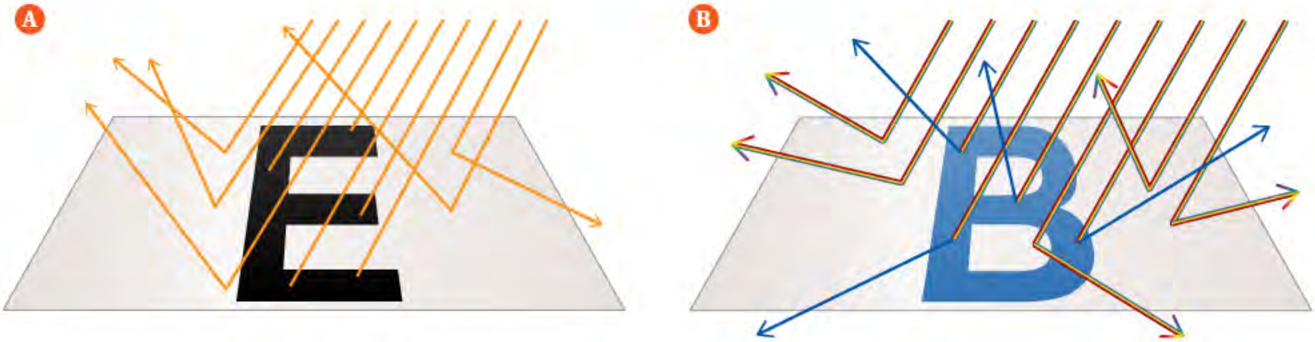
Absorption: Light Energy Is Trapped

Absorption is the process in which light energy becomes trapped in an object as heat. Consider a piece of paper again, but this time one with a black letter on it, as in Figure 3.20A. Reflection off a rough surface lets you see the paper itself. However, the printed letter is made up of black ink that completely absorbs all incoming light. No rays reflect off the letter into your eyes, so it looks black.

absorption the process in which light energy is trapped in an object as heat

What if the letter is a colour? You see colour when an object absorbs only part of the visible light spectrum. Some wavelengths of light are absorbed, and the rest are reflected. Figure 3.20B shows what happens when the letter on the paper is a colour, such as blue. The letter absorbs all colours except blue. The blue wavelengths are reflected from the letter into your eyes, so it looks blue.

Figure 3.20 Ⓐ Rays that hit the black letter are absorbed, so the letter looks black. Ⓑ The blue letter absorbs all wavelengths of visible light except blue. Only the blue light reaches your eyes.



Transmission: Light Passes Through

transmission the process in which light passes through a medium and keeps travelling

Not all materials absorb or reflect all of the light that hits them. Some materials allow different amounts of light to pass through. For example, if you hold a white piece of paper to a light, some light comes through. When light passes through a material, that material is called a *medium*. **Transmission** is a process in which light passes through a medium and keeps travelling. Different materials transmit different amounts of light. For example, a clear glass window transmits more light than a sheet of paper.

Refraction: The Path of Light Bends

refraction the process in which light changes direction when it moves from one medium to another

Light does not change direction when it is travelling through the same medium. However, light does change direction when it moves from one medium to another. This process is called **refraction**. Figure 3.21 shows light refracting.

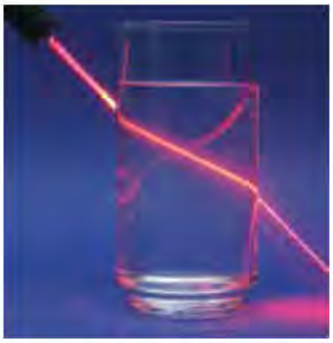


Figure 3.21 This beam of red light allows you to see the path of light bend as it enters and leaves the water.

Use Figure 3.22 to see how refraction can trick your brain. The light reflected from the top part of the pencil travels in a straight line to your eyes through the medium of air. The light from the bottom part refracts. It changes direction slightly as it moves from water to glass to air. (Because light travels such a short distance through the glass, you don't really notice the change in direction caused by the glass.) Your brain believes light always travels in a straight line, so it has trouble determining the position of the bottom of the pencil. That's why the pencil looks broken at the water line.

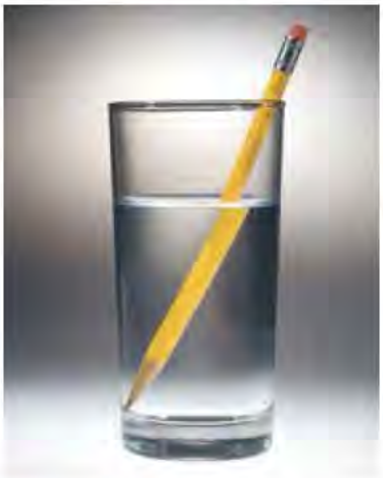


Figure 3.22 This pencil appears broken due to refraction. In reality, the bottom part of the pencil is not where your brain thinks it is.

Before you leave this page . . .

1. Use a flowchart to describe what can happen to light when it strikes an object.
2. The Moon is not a source of visible light. Why does it seem to glow brightly at night?

CONCEPT 2

Light behaves differently when it encounters transparent, translucent, or opaque materials.

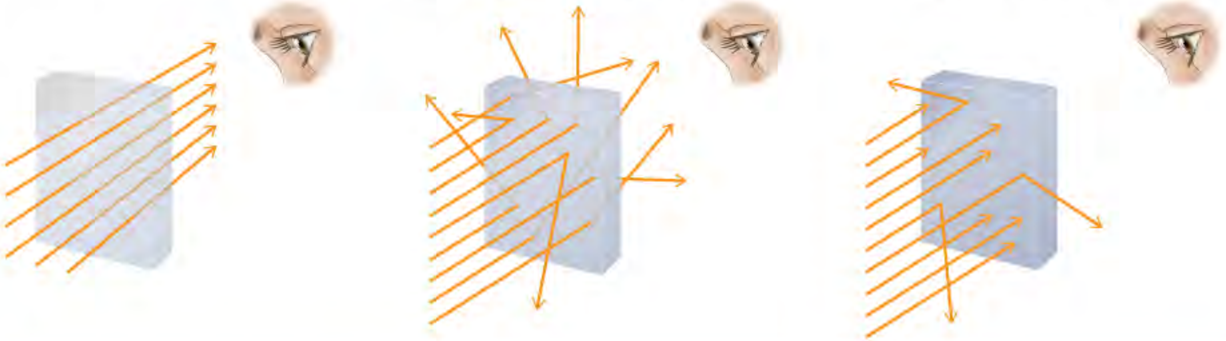
Activity

How Is Light Transmitted?

Inspect the materials your teacher gives you. Predict what happens to light as it strikes each one. Use a flashlight to test your predictions. Use your observations to refine your original predictions.

Figure 3.23 shows that a material can be transparent, translucent, or opaque based on how much light it lets pass through, how the light behaves, and if you can see through it.

Figure 3.23 Light interacts with different materials in different ways.



Transparent Materials Transmit Light

Transparent materials transmit almost all the light rays that strike them. Clear glass, plastic, water, and air are examples of transparent materials. Because transparent materials transmit most light, objects can be seen clearly through them.

Translucent Materials Scatter Light

Translucent materials allow most light to pass through them. However, the light is scattered in many directions as it passes through. Frosted plastic and waxed paper are examples of translucent materials. Because translucent materials scatter light, objects seen through them are usually blurry.

Opaque Materials Reflect and Absorb Light

Opaque materials reflect and absorb light. These materials do not allow any light to pass through them. Wood, metal, and stone are examples of opaque materials. Because opaque materials do not allow light to pass through, objects cannot be seen through them.

Before you leave this page . . .

1. Choose a material from your daily life.
   - **a)** Is the material transparent, translucent, or opaque? How could you confirm your decisions?
   - **b)** Explain how the material's interaction with light is related to its function.
2. Some jellyfish are transparent. How might this affect their ability to survive?

AT ISSUE How can natural optical phenomena be explained?

What's the Issue?

If you live near Golden, you may have caught a glimpse of a rainbow in the spray at Lower Bugaboo Falls. If you live near Kamloops or Osoyoos, you may have witnessed a mirage on the highway in the intense summer heat. The northern sky is a great place to observe a sundog—have you seen one? These optical phenomena occur as a result of light interacting with different materials of the atmosphere, such as water, dust, and ice crystals. As well as rainbows, mirages, and sundogs, other examples include the blue colour of daytime sky, the red colour of evening sunsets, auroras such as the Northern Lights, and cool-sounding crepuscular rays.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

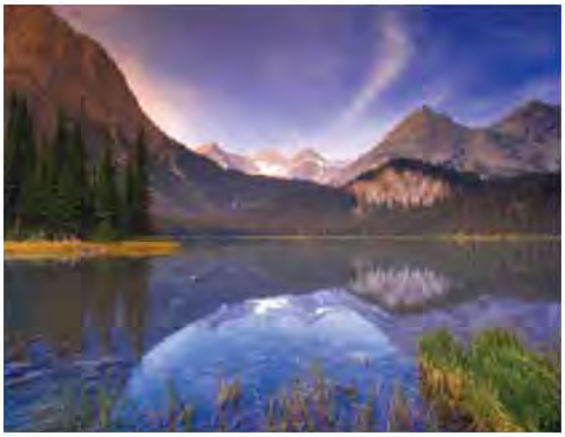
1. What natural optical phenomena have you seen in B.C. and/or elsewhere? What sort of conditions were present when you saw them? For example, you might consider the time of day or year, the temperature, or the weather.
2. Choose at least one natural optical phenomenon. Investigate how it is understood scientifically as well as by other systems of knowing, such as the Traditional Ecological Knowledge of First Peoples. How do the different understandings compare—for example, what do we learn from one way that we don't learn from another? Is something lost (or gained) by using only one way to understand the optical phenomenon?

Check Your Understanding of **Topic 3.3**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. What materials do you know that reflect light? Give three examples. PA
2. What materials do you know that absorb light? Give three examples. PA
3. What materials do you know that transmit light? Give three examples. PA
4. Use the concepts of transmission, scattering, absorption, and reflection to explain what happens to visible light when it strikes each surface below. PA E AI C
   - **a)** a transparent glass window
   - **b)** a window covered by sheer curtains
   - **c)** a window covered by blackout blinds
5. Explain why you can see your face reflected in a smooth glass mirror but not in a sheet of smooth white paper. PA C
6. The photo below was taken at Elk Lakes Provincial Park in the southeast part of B.C. Identify all the places you can see in this photo where light is being reflected, refracted, absorbed, and transmitted. PA E AI



7. What would the world look like if the following situations existed on Earth? Justify your responses. PA AI C
   - **a)** objects no longer reflect light
   - **b)** materials cannot transmit light
   - **c)** all wavelengths of visible light are either reflected or absorbed (there is no in between)
   - **d)** all objects transmit light

Connecting Ideas

8. Think about a typical school day. As you do your usual activities, you use many devices and objects. List three ways in which you use each of the following: PA AI
   - **a)** something with an extremely smooth surface
   - **b)** a transparent material
   - **c)** an opaque object
   - **d)** something that absorbs most light that reaches it

Making New Connections

9. Design an educational game based on the properties of transparent, translucent, and opaque materials. PA AI
10. Scientists have invented materials, called metamaterials, that cause light to behave in ways that it normally would not. It bends around the material and reconnects behind it, like water flowing around a rock or stump in a stream. Scientists hope one day to use metamaterials to make things appear invisible. Suggest a possible application for metamaterials that would benefit society. E AI

INVESTIGATION

3-G

STRUCTURED INQUIRY AND GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

Safety

- The edges of the mirrors may be sharp. Be careful not to cut yourself.
- Be careful not to drop the mirrors.
- Never shine a light directly into someone's eyes.

What You Need

- a variety of objects and materials that reflect, absorb, transmit, scatter, or refract light
- construction materials, such as tape, glue, and scissors
- flashlight
- access to information resources

Exploring How Light Interacts with Different Materials

PART A: CREATE A LIGHT SCULPTURE—STRUCTURED INQUIRY

Question

How can you create a sculpture to demonstrate how light behaves when it strikes different materials and objects?

Procedure

1. Your teacher will provide objects and materials that reflect, absorb, transmit, scatter, or refract light. Use any of these to build a sculpture that will create various effects when light shines on it in a darkened room.
2. Copy the following table and give it an appropriate title.

Material or object	Predicted effects	Observed effects

3. Record each material or object that you plan to use.
4. For each, predict the effects you think it will create, as well as how you think light will behave. Add your predictions to your table.
5. Design and build your sculpture.
6. Your teacher will darken the room or take you to another room where this is possible. Shine light on your sculpture. Observe and record the effects, as well as how light interacts with each material or object. Add your observations to your table.

Analyze and Communicate

1. Explain the understandings you used to make your predictions. How well did they match your observations?

PART B: APPLY YOUR UNDERSTANDING—GUIDED INQUIRY

Blackfoot architect Douglas Cardinal, reflecting on the designs he created for Canada's Museum of Civilization in Ottawa, said: "Instead of viewing the museum as a sculptural problem…I prefer to take a walk in nature, observe how nature has solved its problems, and let it be an inspiration to me in solving mine." He believes, "Our buildings must be a part of nature, must flow out of the land; the landscape must weave in and out of them so that, even in the harshness of winter, we are not deprived of our closeness with nature."

Architects like Douglas Cardinal, as well as other artists and designers, make use of materials that interact with light in different ways. They use the materials to create desired effects in their creative works.

Question

How can you apply your understanding of light and materials to achieve intended effects?

Procedure

1. Choose an artist, architect, or designer who interests you. Do research to find out how the materials that he or she works with interact with light and what techniques can be used to create different effects of light, shadow, and colour.
2. Reflect on your findings. Decide how you can apply your understanding in designing a creation of your own. This could be a building plan, a painting, a garden, a ceremonial space, a stage set for a performance, or anything else you choose.

Evaluate and Communicate

1. In the research stage of your inquiry, what did you discover that you did not know before? How else did your research introduce you to new ideas or help you refine ideas you already had?
2. How did your research help you develop your plan for your creation?
3. How can you use input from others to help you assess and refine your creation?

TOPIC 3.4

How does light behave when it is reflected?

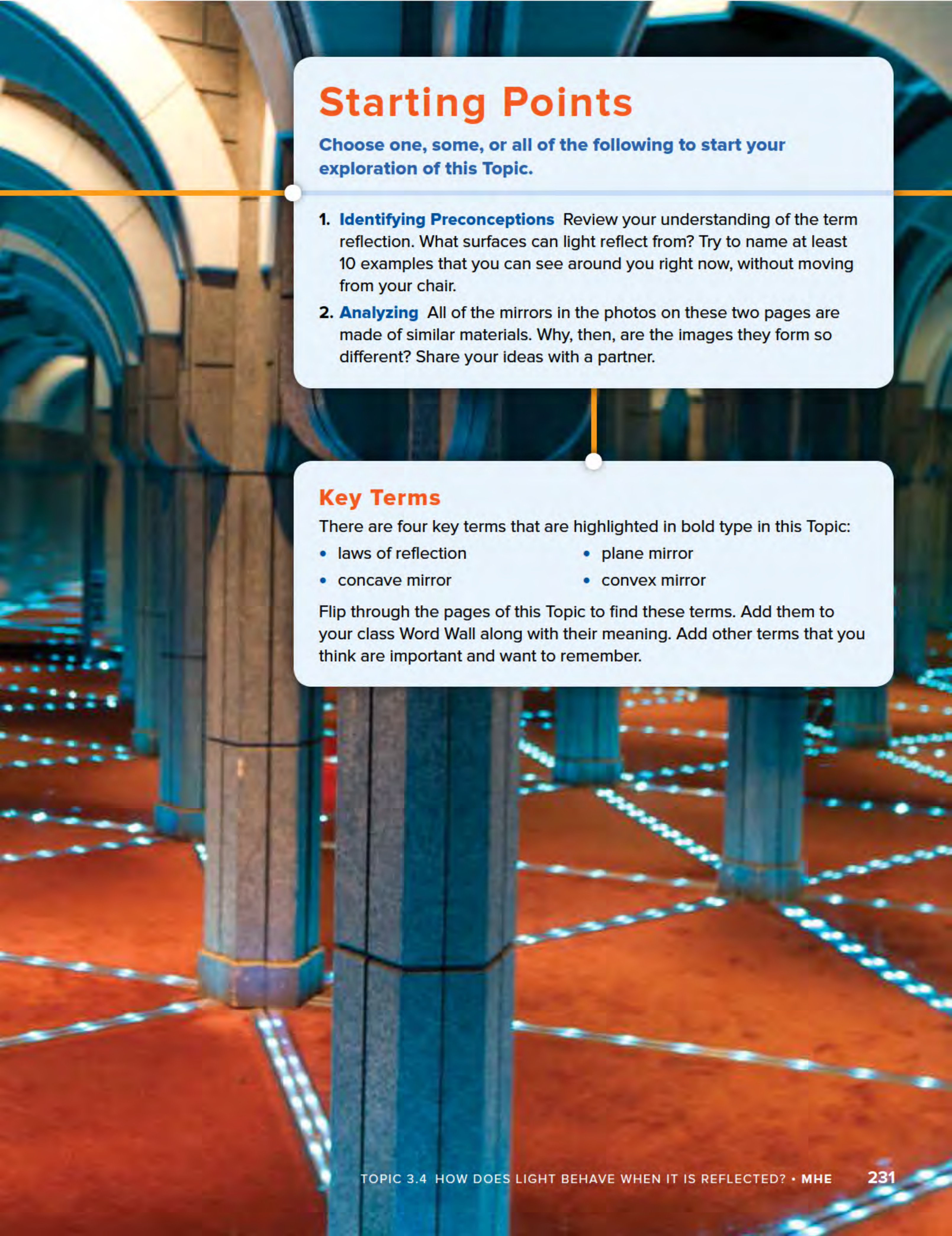
Key Concepts

- Light is reflected in predictable patterns.
- Light reflected by a plane mirror produces an image that is nearly identical to the object.
- Light reflected by curved mirrors behaves in unique ways.
- Many technologies take advantage of light's behaviour when it strikes a reflective surface.

Curricular Competencies

- Seek patterns and connections in data
- Use scientific understandings to identify relationships and draw conclusions
- Construct and use a range of methods to represent patterns or relationships in data
- Measure and control variables through fair tests

Funhouse mirrors are designed to amuse and confuse. Some, like the ones in the maze shown here, form clear images that are almost identical to the objects they reflect. When they are cleverly placed in the maze, you may find yourself walking into one that forms an image of an empty hallway. Other funhouse mirrors form misshapen images like the ones in the insets.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Review your understanding of the term reflection. What surfaces can light reflect from? Try to name at least 10 examples that you can see around you right now, without moving from your chair.
2. **Analyzing** All of the mirrors in the photos on these two pages are made of similar materials. Why, then, are the images they form so different? Share your ideas with a partner.

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- laws of reflection
- concave mirror
- plane mirror
- convex mirror

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Light is reflected in predictable patterns.

Light rays always follow a predictable path, no matter what surface they reflect from. Three key ideas determine this path. These ideas are called the **laws of reflection**. Use Figure 3.24 to help you understand them.

laws of reflection three laws that describe the predictable path light follows when it strikes a reflective surface

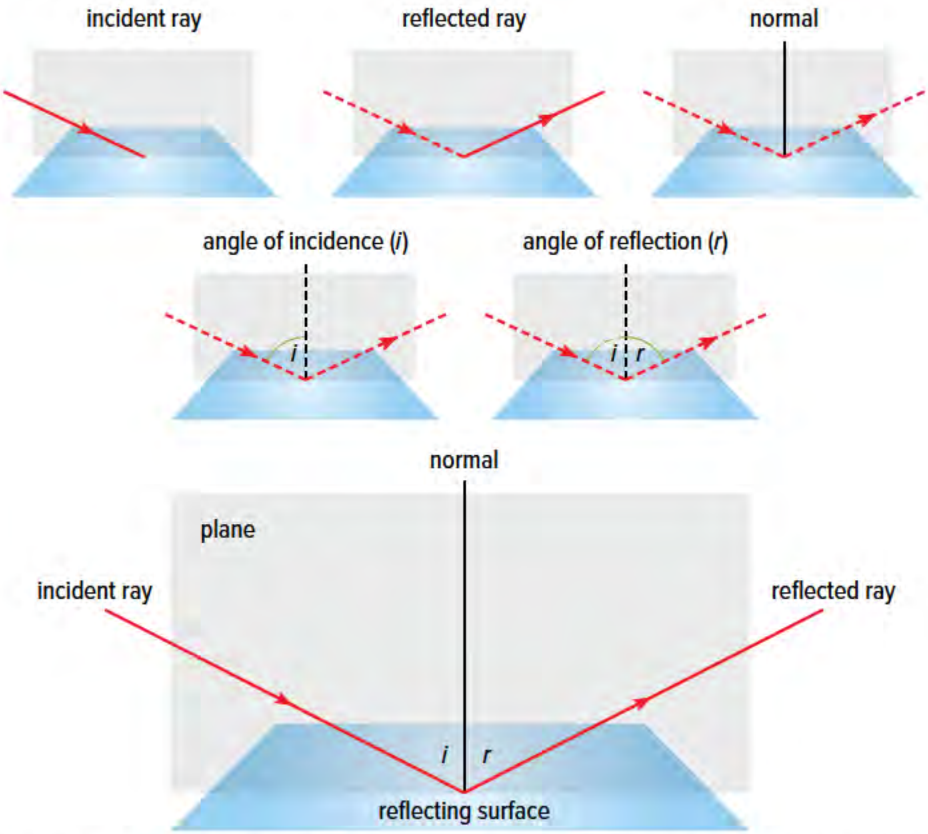

incident ray
reflected ray
normal
angle of incidence (*i*)
i
angle of reflection (*r*)
i
r
normal
plane
incident ray
reflected ray
i
r
reflecting surface

Figure 3.24 All light rays obey the laws of reflection, as shown here. The word *plane* refers to any flat surface.

incident ray: the light ray travelling toward the reflecting surface

reflected ray: the light ray that has bounced off a reflecting surface

normal: a line perpendicular to a surface such as a mirror

angle of incidence (*i*): the angle between the incident ray and the normal

angle of reflection (*r*): the angle between the reflected ray and the normal

Laws of Reflection

- The angle of reflection (r) is equal to the angle of incidence (i).
- The reflected ray and the incident ray are on opposite sides of the normal.
- The incident ray, the normal, and the reflected ray lie on the same plane (flat surface).

Visualizing the Laws of Reflection

You can use a game of pool to help you visualize the laws of reflection. If the player shoots a ball into a bumper head-on (perpendicular to it), the ball will bounce straight back in the opposite direction (**Figure 3.25A**). If the player shoots the ball so it strikes the bumper at an angle, the ball will also bounce off at this angle, but in the opposite direction (**Figure 3.25B**).

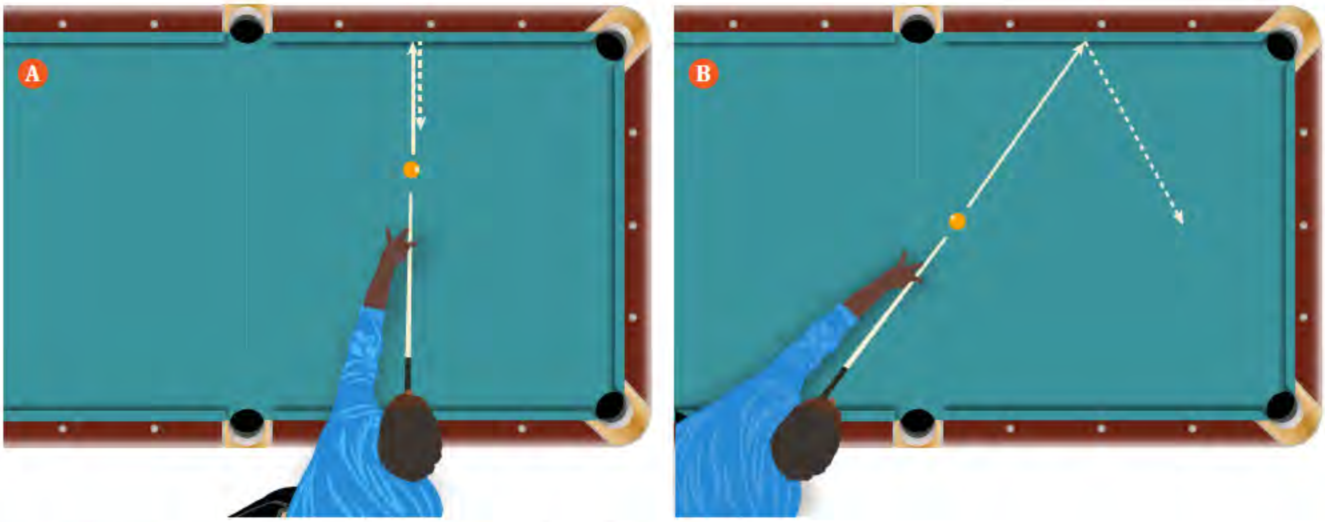


Figure 3.25 Pool shots made head-on Ⓐ and at an angle Ⓑ can help you visualize the laws of reflection.

Activity

Game On!

Sometimes the best way to remember something is to make a game of it.

Design a game to help you and your classmates remember the terms introduced in this Concept, as well as the laws of reflection. The form your game takes is up to you. Have others play your game to see how effective it is, and use their feedback to make improvements.

Before you leave this page . . .

1. What do the angle of reflection and the angle of incidence have in common? Consider how they are measured and how they compare to one another.
2. Why does an expert billiards (pool) player need to understand the laws of reflection to make an accurate shot?

CONCEPT 2

Light reflected by a plane mirror produces an image that is nearly identical to the object.

Activity

Reflection Obstacle Course

Safety: Do not shine a light directly in someone's eyes.

1. Reflect light from a flashlight off two flat mirrors to hit a target.
2. Reflect light from an infrared remote control off two mirrors to turn on a remote-controlled device.
3. Explain how this activity demonstrates the laws of reflection.

An extremely smooth, flat reflective surface like the one in Figure 3.26 is called a **plane mirror**. Figure 3.27 shows how an image forms in a plane mirror.

- When light shines on an object, such as the tomato, it reflects off all points of the object in all directions.
- When some of these reflected rays reach the plane mirror, they follow the laws of reflection and reflect backwards.
- Some rays reach your eyes if you are looking at the mirror. They carry the same pattern of light to the eye that was reflected off the tomato. The brain assumes light travels in a straight line and thinks the image is behind the mirror.

plane mirror an extremely smooth, flat reflective surface

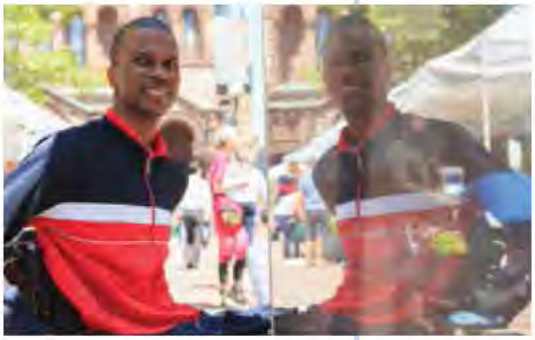


Figure 3.26 Reflection in a plane mirror.

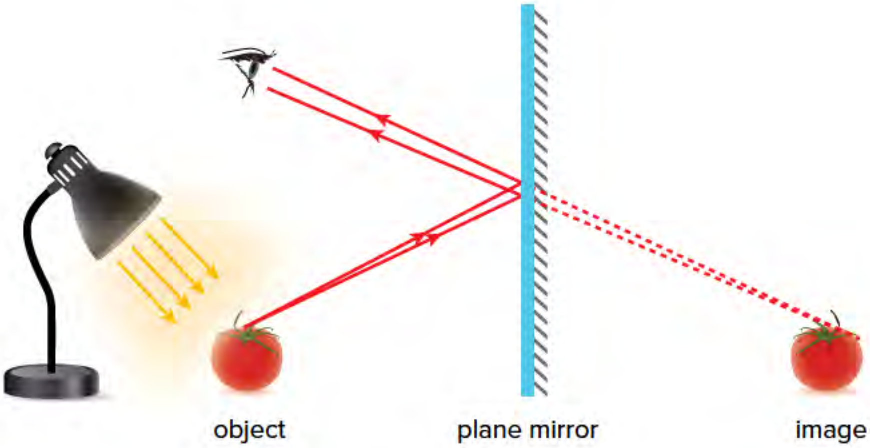


Figure 3.27 Light rays follow the laws of reflection when they reflect from a plane mirror. To find out where the image appears to be, you can extend the reflected rays backwards until they meet. This is shown by the dotted line.

Characteristics of Images

Now that you know how an image forms in a plane mirror, what characteristics does it have? To answer this question, it helps to know the different characteristics an image can have. These apply to any images, not just images in plane mirrors.

Four Characteristics of Images

Location: An image may be closer to or farther from the mirror than the object. The object may also be the same distance from the mirror as the object.

Orientation: An image may be upright or inverted (upside-down).

Size: An image may be the same size as, larger than, or smaller than the object.

Type: An image may be real or virtual.

A *virtual image* is not a real image. In Figure 3.27 no light rays are going to or coming from the image behind the mirror. Light rays only appear to be coming from the image. The reflected rays do not actually meet. Only the extended rays do. Your brain imagines that an image forms behind the mirror. There is no way that light could get there.

A *real image* is formed when reflected rays (not extended rays) meet. While virtual images form behind the mirror, real images are located in front of the mirror. If you place a screen at the position of a real image, the rays will meet at the screen and form an image. An image on a movie screen is a real image.

Images in Plane Mirrors

Look at Figure 3.26 and 3.27 again. Notice that an image in a plane mirror

- is the same size as the object
- is the same distance from the mirror as the object
- is upright
- is a virtual image.

A plane mirror produces an image that is nearly identical to the object. But Figure 3.28 shows a difference. The image is reversed compared to the object. The direction of the reversal depends on the position of the object and the mirror. For example, when you see the image of mountains in a lake, the reversal is in the vertical direction. While the orientation of the mountains remains upright, reversals can make you think it does not. If the angle of the mirror is changed, the image looks upright again.

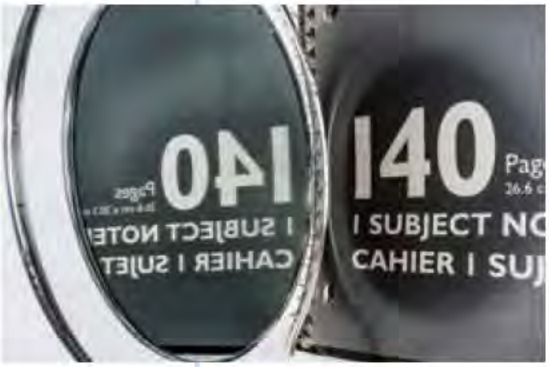


Figure 3.28 This image in a plane mirror appears reversed. Can you write your name on paper while looking only in a plane mirror? What do you observe about the writing on the paper?

Before you leave this page . . .

1. What is meant when the image is said to be behind the mirror? What do you call this type of image?

CONCEPT 3

Light reflected by curved mirrors behaves in unique ways.

Activity

Exploring Curved Mirrors

1. Hold a plane mirror about 25 cm from your face and observe the image. Move the mirror toward your face, as well as away. Observe any changes.
2. Hold a concave mirror or the inside of a spoon about 25 cm from your face. Observe the image. Move the mirror or spoon toward your face until you no longer see an image. Then move it as far away as possible. Observe any changes in your image.
3. Look at your reflection in a convex mirror or on the back of the spoon. Hold the mirror or spoon close to your face and slowly move it away. Notice how your image changes.
4. Discuss your observations as a class.

The sculpture in Figure 3.29 is called Sky Mirror. The mirror's reflective surface is made from polished stainless steel.

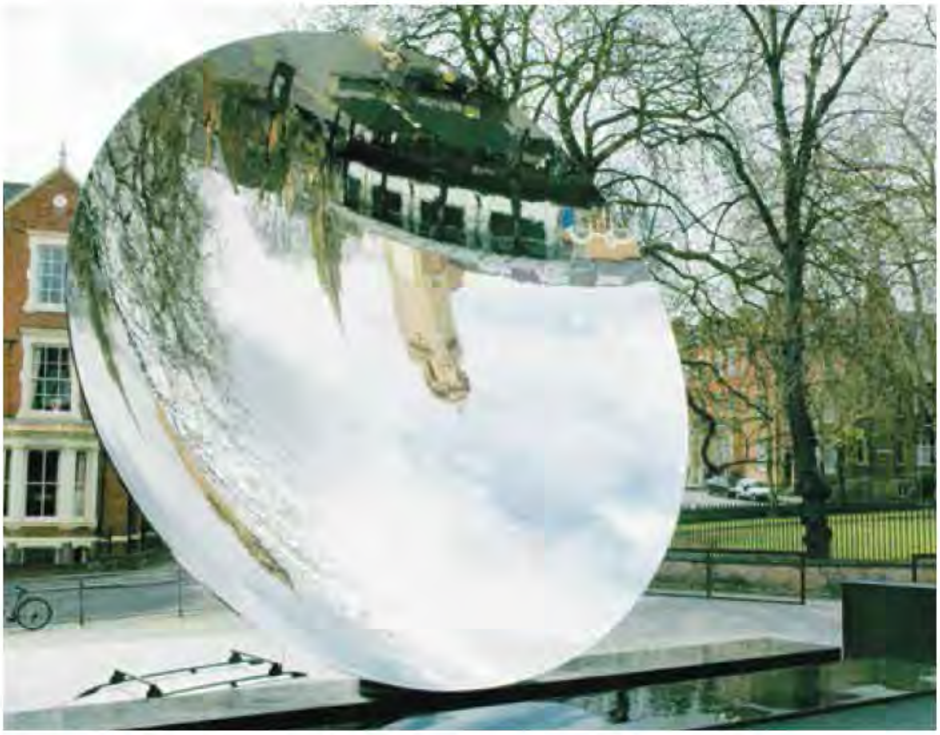


Figure 3.29 Sky Mirror is a curved mirror created by artist Anish Kapoor. What properties of the image in Sky Mirror are different from those seen in plane mirrors?

Compare what you see in Sky Mirror's reflective surface to what you see in the reflective surface in Figure 3.30. This sculpture is called Cloud Gate. Its reflective surface is made of the same material as Sky Mirror. The images reflected in these two sculptures are very different, but there are also similarities. Sky Mirror and Cloud Gate are both *curved mirrors*. You just learned that a plane mirror produces an image that is nearly identical to the object. With curved mirrors, this is not the case.

Connect to Investigation 3-H on page 244

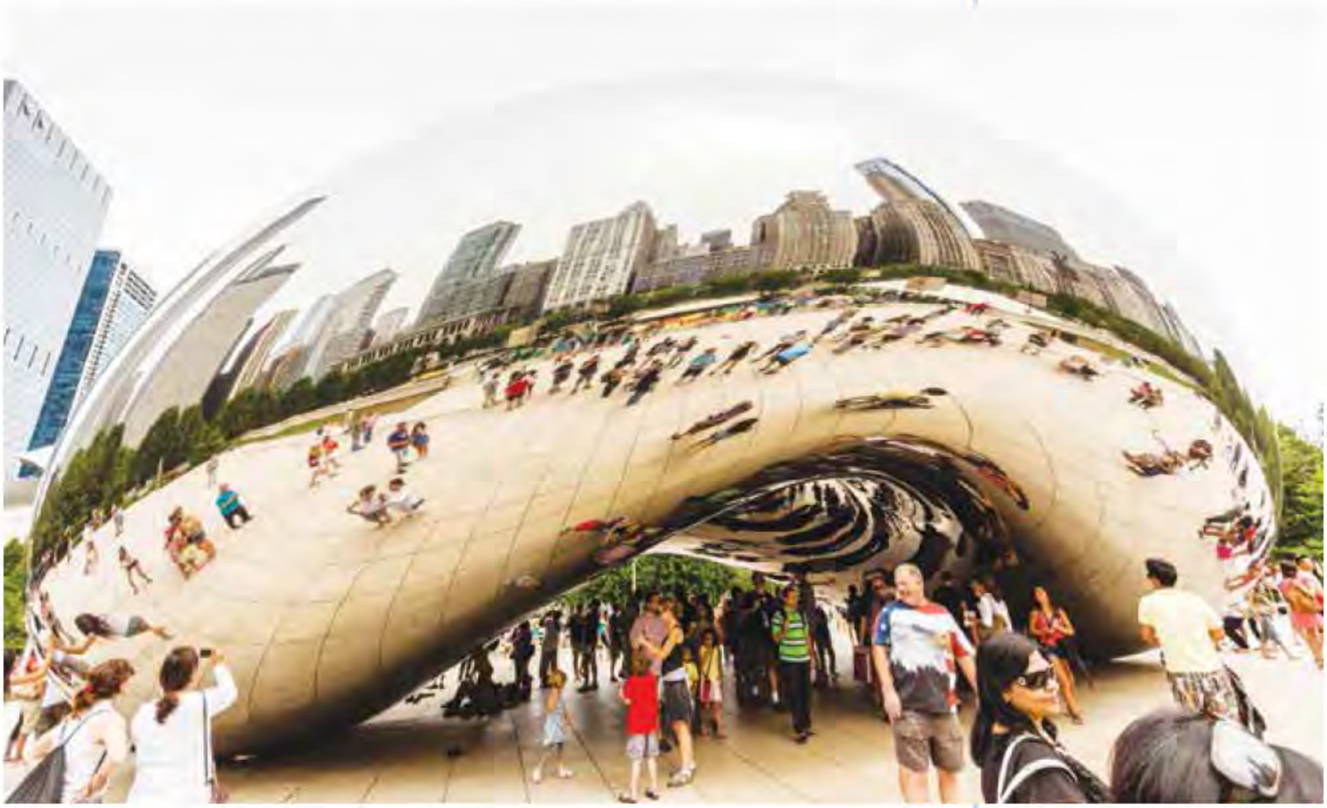


Figure 3.30 Cloud Gate is another curved mirror created by Anish Kapoor. How is the image in Cloud Gate similar to the one in Sky Mirror? How is it different?

Concave and Convex: Two Types of Curved Mirrors

The portion of Sky Mirror shown in Figure 3.29 is a **concave mirror**. A concave mirror is curved inward like the inner bowl of a spoon. You can remember a concave mirror as a mirror that "caves in" at the centre. The portion of Cloud Gate shown in Figure 3.30 is a convex mirror. A **convex mirror** is curved outward like the back of a spoon.

concave mirror	a mirror with a reflecting surface that curves inward
convex mirror	a mirror with a reflecting surface that curves outward

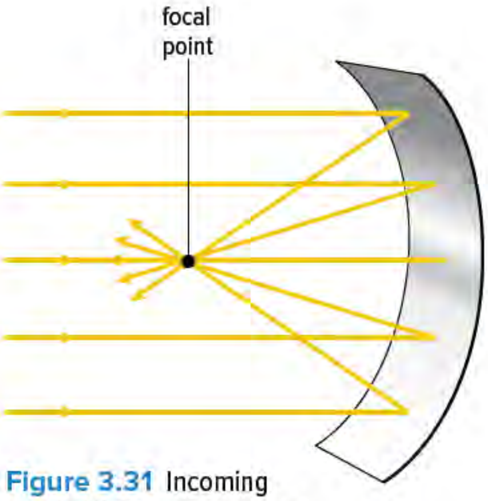


Figure 3.31 Incoming parallel light rays converge when they reflect off a concave mirror.

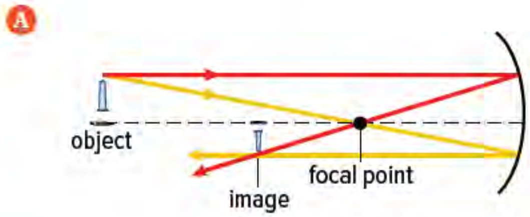
Images in Curved Mirrors

Light rays behave in unique ways when they are reflected off a curved mirror. As you saw in Sky Mirror and Cloud Gate, images in curved mirrors are never identical to the objects they are reflecting.

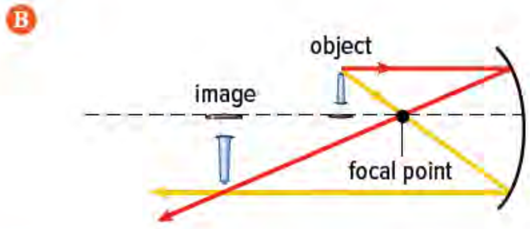
Images in Concave Mirrors

As shown in Figure 3.31, when incoming parallel light rays reflect off a concave mirror, they come together at a single point. This point is called a *focal point*. When the light rays meet at the focal point, they are said to converge. Converge means "to bring together."

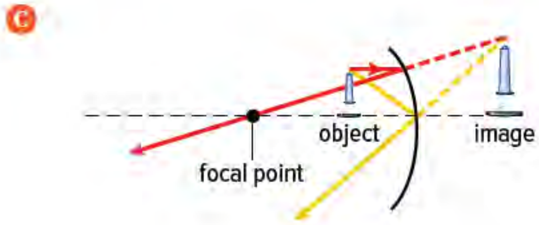
The characteristics of the image formed by a concave mirror depend on where it is located compared to the surface of the mirror and the focal point. This idea is explained in more detail in Figure 3.32. Images in a concave mirror, such as the buildings and trees in Sky Mirror, are misshapen, especially toward the edges of the mirror.



A distant object is located far from the focal point. It is reflected to produce a smaller, inverted (upside-down) image. The rays meet, so the image is real. The image is closer to the mirror than the object.the mirror than the object.



The object moves closer to the focal point, but not between the focal point and the concave mirror. It is reflected to produce a larger, inverted image. The rays meet, so the image is real. The image is farther from the mirror than the object.



The object moves between the focal point and the concave mirror. The image becomes even larger and is now upright. The reflected rays do not meet, so you have to extend them in the opposite direction. Therefore, the image is virtual. The image is farther from the mirror than the object.

Figure 3.32 Images in a concave mirror.

Images in Convex Mirrors

When parallel light rays are reflected off the surface of a convex mirror, they spread apart after they bounce off the mirror's reflective surface. They are said to *diverge*. Diverge means "to spread out in different directions." If the diverging rays are extended back behind the mirror, it looks like they arise from a focal point behind the mirror. Figure 3.33 shows how only the extended rays meet at a focal point. The actual rays do not meet. This means that an image produced by a convex mirror is always a virtual image, just like an image in a plane mirror.

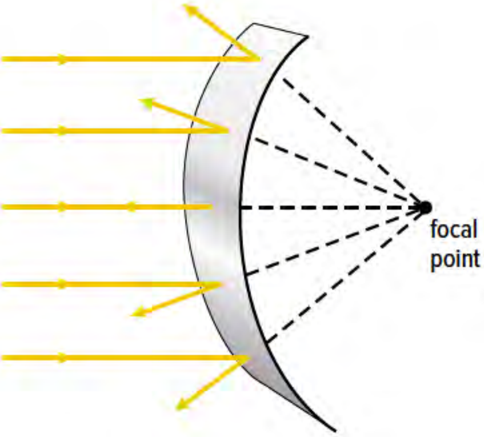


Figure 3.33 Incoming parallel light rays diverge when they reflect off a convex mirror.

The characteristics of an image formed by a convex mirror do not depend on where the object is located. All reflections in convex mirrors have the same characteristics:

1. The image is smaller than the object.
2. The image is closer to the mirror than the object.
3. The image is a virtual image.
4. The image is upright.

More objects can be seen in a convex mirror than in a plane mirror of the same size. This is because convex mirrors reflect light from a large incoming area. Images in convex mirrors are also distorted, especially at the edges. Only the image in the small centre region is not misshapen.

Before you leave this page . . .

1. Use a T-chart to compare a convex mirror with a concave mirror.
2. Convex mirrors are often used as security mirrors in convenience stores. Explain why.

CONCEPT 4

Many technologies take advantage of light's behaviour when it strikes a reflective surface.

Activity

Up, Periscope!

What is a periscope and how is it used? What do you need to build your own working model of a periscope? With a partner, decide on a plan for building a periscope using easily available materials. If possible, build and test it, and reflect on how you could improve its design.

Mirrors and other reflective surfaces have a lot of uses. Some are used to reflect images, but often their ability to reflect visible light and other types of electromagnetic radiation is where they really shine!

Curved Reflective Surfaces

Concave mirrors are often used to concentrate light. When a light source is located exactly at the focal point, the rays that strike the mirror are reflected parallel to each other. This produces a very intense beam of light that is used in car headlights and flashlights.

Curved reflective surfaces also play an important role in radar technology. *Radar* stands for **ra**dio **d**etection **a**nd **r**anging. One of its main uses is to detect aircraft. The radar antenna in **Figure 3.34** uses a concave reflective surface to do this. A radio wave generator and detector are located at the focal point of the antenna. First, a pulse of radio waves is generated and sent out toward the sky. The rounded surfaces on a typical airplane are convex reflective surfaces. At least some part of the surface is perpendicular to incoming radar waves and will reflect the waves directly back to the antenna. The antenna's concave surface directs the reflected rays to the detector at the focal point to locate the airplane.

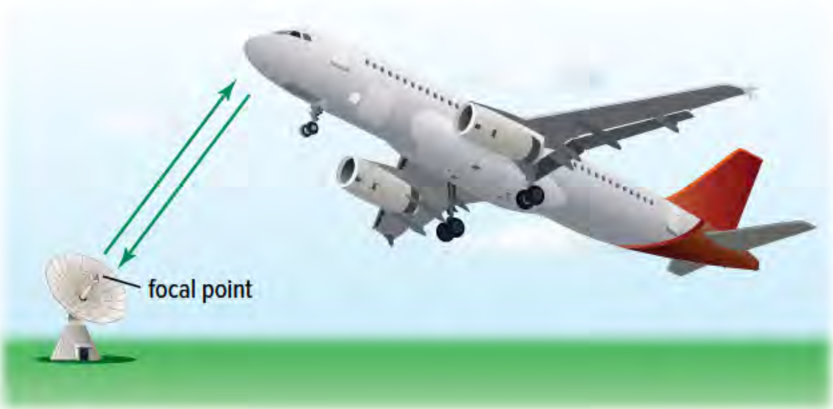
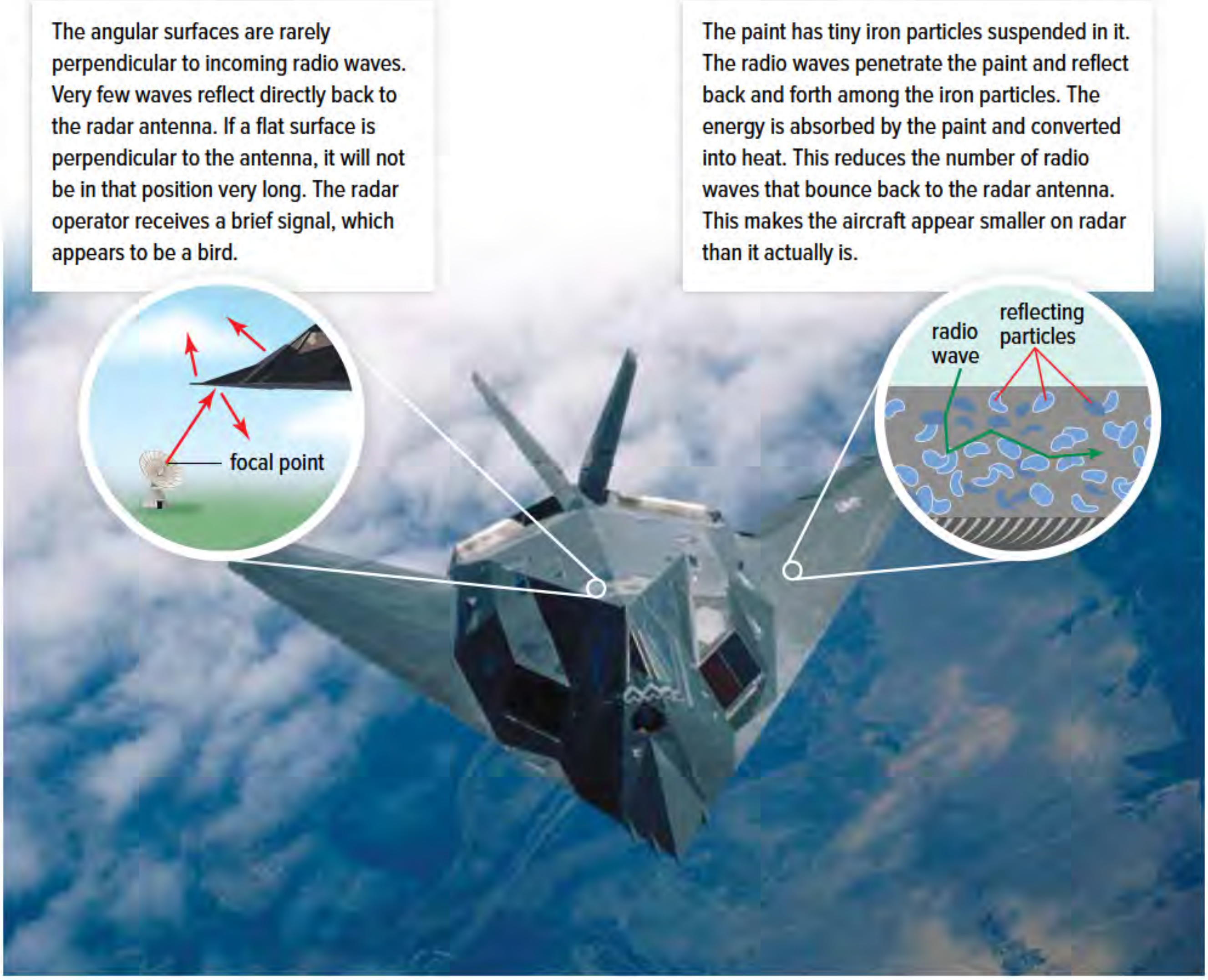


Figure 3.34 Concave and convex reflective surfaces both play a role in aircraft detection by radar.

Plane Reflecting Surfaces

Military aircraft such as the stealth fighter need to avoid radar detection. Two features make the aircraft almost invisible to radar. These are explained in **Figure 3.35**.

Figure 3.35 Plane reflecting surfaces help this Lockheed F-117 Nighthawk avoid radar detection.



The angular surfaces are rarely perpendicular to incoming radio waves. Very few waves reflect directly back to the radar antenna. If a flat surface is perpendicular to the antenna, it will not be in that position very long. The radar operator receives a brief signal, which appears to be a bird.

The paint has tiny iron particles suspended in it. The radio waves penetrate the paint and reflect back and forth among the iron particles. The energy is absorbed by the paint and converted into heat. This reduces the number of radio waves that bounce back to the radar antenna. This makes the aircraft appear smaller on radar than it actually is.

Before you leave this page . . .

1. Explain how car headlights create an intense beam of light.
2. Radio telescopes can detect radio waves from outer space. What shape would a radio telescope most likely be and why?

AT ISSUE How Can Mirror Technology Help Us See in New Ways?

What's the Issue?

Mirrors can help us see beyond the vision of the unaided eye. Omnidirectional cameras use curved mirrors to record images and video in all directions at once. The doughnut-shaped image at the bottom of this page was captured using an omnidirectional camera on a ship in Alaskan waters. A spherical panorama of the image is also shown.

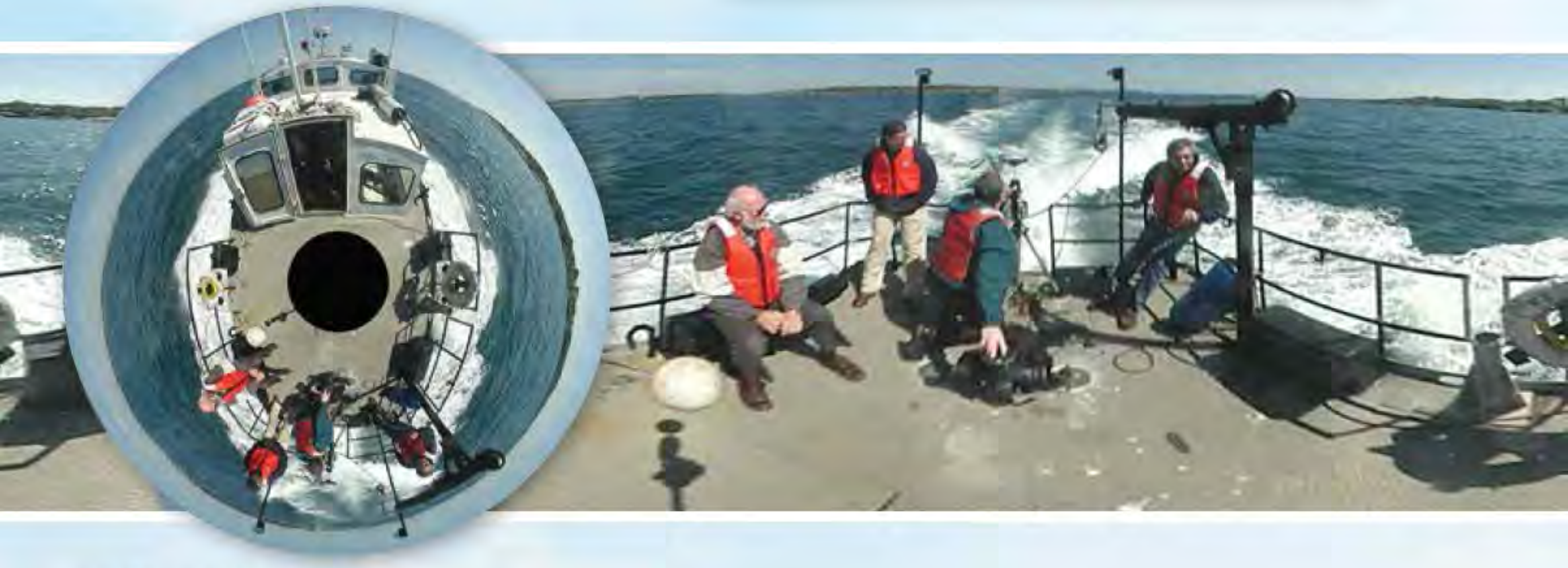
One high-profile use for omnidirectional cameras is on the Mars Exploration Rovers. These robotic geologists on wheels were launched in 2004 as part of NASA's mission to find clues of past water activity in the rocks and soil on Mars. Only one rover is still operational. Its omnidirectional camera allows its controllers back on Earth to see in all directions as they drive the rover remotely. It also gives scientists a great deal of information about the surface of Mars.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Find out more about another technology that uses reflection. Choose one of the following technologies, or find another that interests you.
   - holograms
   - glitter cloud telescope
   - rear view motorcycle helmet
   - reflecting telescope

   Research the technology to understand how it works and how it is used. Use this information to create an advertisement for the technology. Your advertisement should explain how the technology uses reflection. The format is up to you.
2. Omnidirectional cameras aren't just useful on Mars. Suggest one way an omnidirectional camera could be used on Earth. Why would an omnidirectional camera be beneficial for this application?



Check Your Understanding of **Topic 3.4**

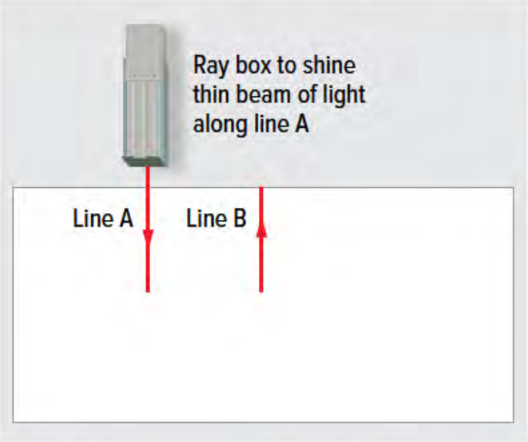
QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Make a simple, accurate drawing in which you show and label the following: PA C
   - an incident ray
   - a reflected ray
   - the normal
   - the angle of incidence
   - the angle of reflection

2. Makeup mirrors usually have two sides. On one side, the mirror is flat, and on the other side the mirror is slightly curved inward. PA AI
   - **a)** What are the correct terms to describe the two types of mirrors?
   - **b)** How do the images that you see in the two mirrors differ from each other?
   - **c)** Explain why the curved mirror is helpful for applying makeup.

3. Examine the diagram below, which shows a sheet of white paper with straight lines drawn on different parts of it. QP PC PA AI



Predict how you could use mirrors to make a light ray that travels along Line A reflect back along Line B. How can you test your prediction?

4. You are looking in an amusement park mirror. Your image appears smaller than you and closer to the mirror than you are. Your image is upright and looks like it is behind the mirror. PA
   - **a)** What type of mirror are you looking at?
   - **b)** Explain how you decided on your answer.

5. Describe all the ways that an image in a mirror can differ from the original object. PA C

Connecting Ideas

6. In large warehouses where forklifts are used to transport large crates, you often see convex mirrors like the one below hanging from the ceiling. E AI

   - **a)** What do you think is the purpose of these mirrors?
   - **b)** Why are convex mirrors used instead of plane mirrors?

Making New Connections

7. Design an efficient "hotdog oven" that uses energy from the Sun and a mirror made with aluminum foil on a sturdy cardboard backing to cook the hotdog. Make a sketch of your hotdog oven with dimensions included. Write a paragraph to describe how it works. Hint: Think focal line instead of focal point. QP PC AI C

INVESTIGATION

3-H

STRUCTURED INQUIRY AND GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Processing and Analyzing
- Evaluating
- Communicating
- Applying and Innovating

Safety

- The edges of the mirrors may be sharp. Be careful not to cut yourself.
- Be careful not to drop the mirrors.

What You Need

- blank sheet of paper (letter size)
- pencil
- ruler
- small, standing object (such as an action figure)
- hinged plane mirror
- protractor
- a variety of mirrors and materials for Part B

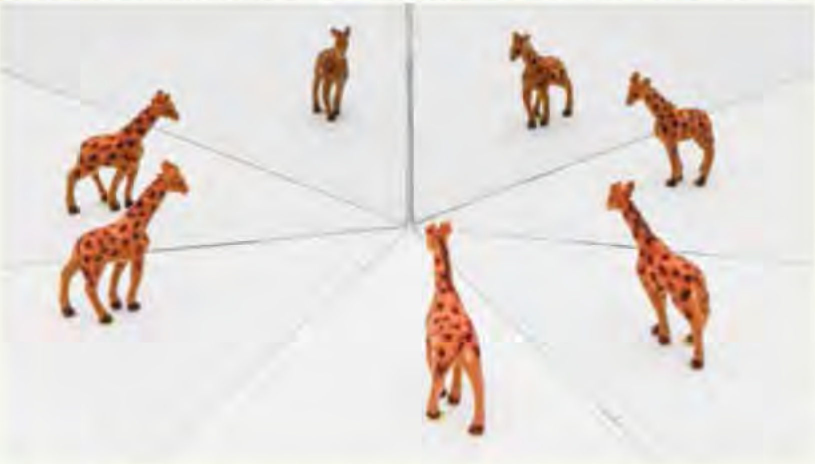
Exploring Mirror Images

Question

How can you create cool effects and investigate characteristics of images using mirrors?

Procedure: Part A—Structured

1. Stand a hinged mirror upright so that both mirrors face you at an angle. Place a small, object between the mirrors.



2. Make the angle between the mirrors smaller and larger. Record any changes you observe in the images that form.
3. Copy the table below.

Angle Measurement	Number of Images
180°	
120°	
90°	
72°	
60°	
45°	
30°	

4. On a piece of paper, use a ruler and protractor to draw the first angle on the table. Place the hinged mirror on the paper. Adjust the sides so that they sit on the angle. Record the number of images you see.

5. Repeat step 4 for every angle in the table.

6. Graph the data in your table. Give your graph a title, and label the *x*-axis and the *y*-axis appropriately.

Procedure: Part B—Guided Inquiry

7. Choose one (or more) of the questions below to investigate, or come up with a question of your own.
   - **a)** How can you use two mirrors to create an infinite (endless) number of images?
   - **b)** How can you use one mirror, a pencil, and paper to form an image of a word that is not reversed left to right?
   - **c)** How can you use a mirror and a projector to project a word on a screen, if the projector and the screen are both facing away from you?
   - **d)** How can you use a mirror and a light source to create an intense beam of light?
   - **e)** How can you use three mirrors to make a kaleidoscope?
   - **f)** How can you use a mirror to make it look (to a viewer) like both your feet are off the ground?

8. With a partner or group, plan how you could answer the question you chose in step 7.

9. Carry out your plan. Assess how well your plan is working as you carry it out. Adjust your plan if necessary.

Process and Analyze

1. Use your graph from Part A to answer the questions that follow.
   - **a)** Write a statement that describes how the number of images changes as the angle between the mirrors changes.
   - **b)** Predict the angle between the mirrors if six images were visible. Explain how you made your prediction.
   - **c)** Predict the number of images you would see if the angle between the mirrors was 20°. Explain how you made your prediction.

2. For Part A, why do you think the number of images changes as the angle between the mirrors changes?

Evaluate

3. For Part B, how well did your plan help you answer the question you chose to investigate?

4. For Part B, did adjusting your plan help you answer the question? If so, explain how.

Apply, Innovate, and Communicate

5. Magic shows have been described as being “all smoke and mirrors.” Do research to find out how mirrors are used in magic shows. Choose one mirror trick and share it with your class, either by describing the trick or performing it for your classmates.

TOPIC
3.5

How does light behave when it moves from one medium to another?

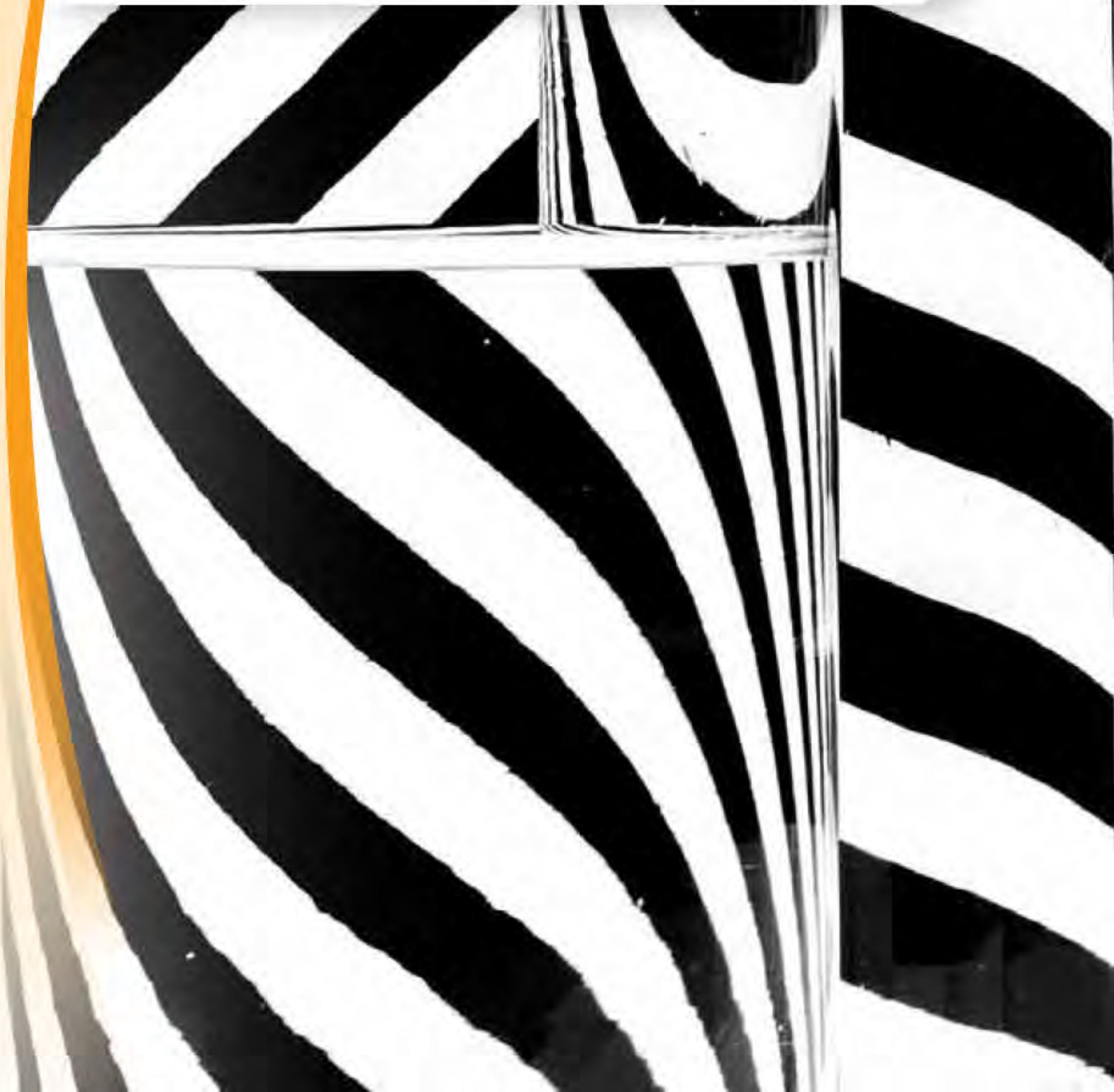
Key Concepts

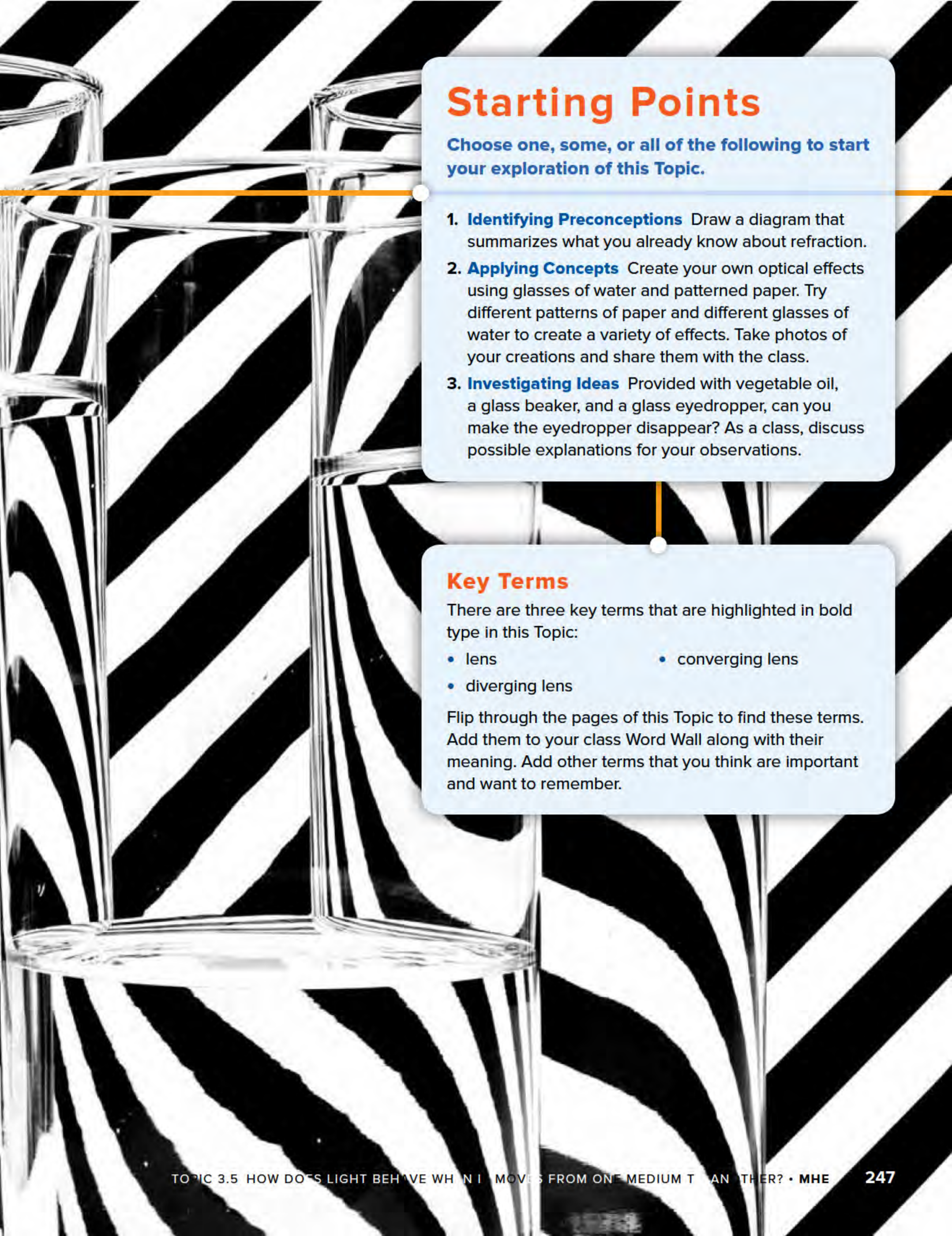
- Light changes direction and speed when it moves from one medium to another.
- Light refracts as it passes through lenses.
- Refraction plays a role in human vision.
- Many technologies take advantage of light's behaviour when it moves from one medium to another.

Curricular Competencies

- Contribute to care for self, others, community, and the world
- Observe, measure, and record data using equipment
- Communicate ideas, findings, and solutions to problems
- Transfer and apply learning to new situations

The photo on these two pages shows several glasses of water placed in front of diagonally striped paper. It was taken with a normal camera lens. What do you think is responsible for the effect you see? The answer lies in how light behaves when it travels from one medium to another. You already know that refraction causes the path of light to bend when it travels from one medium to another. Refraction can trick your brain. Think back to the pencil placed in half a glass of water. It appeared broken due to refraction. In this photo, refraction is creating the same effect. It is causing the brain to "see" some of the diagonal lines where they are not.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Draw a diagram that summarizes what you already know about refraction.
2. **Applying Concepts** Create your own optical effects using glasses of water and patterned paper. Try different patterns of paper and different glasses of water to create a variety of effects. Take photos of your creations and share them with the class.
3. **Investigating Ideas** Provided with vegetable oil, a glass beaker, and a glass eyedropper, can you make the eyedropper disappear? As a class, discuss possible explanations for your observations.

Key Terms

There are three key terms that are highlighted in bold type in this Topic:

- lens
- diverging lens
- converging lens

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Light changes direction and speed when it moves from one medium to another.

Activity

Visualizing Refraction

When light travels from one medium to another, both its speed and direction may change. To visualize this, consider this analogy. What happens if you are riding a bicycle and hit some soft mud? Fill in the blanks below to explain what happens. Compare your answers with others in the class.

The front wheels suddenly ____________, but the back wheels keep travelling at the same ____________. As a result, the bicycle ____________.

You have already learned that light travels in a straight line through the same medium. You also know that when light travels from one medium to another, for example, from air to water, its path refracts (bends). What causes this refraction?

Refraction: Light Travels at Different Speeds and Changes Direction

Refraction occurs because light travels at different speeds in different media. For example, light travels at a different speed through air than it does through water. (Light, and all other types of electromagnetic radiation, only travel at the same speed—3.00×10^8 m/s—in a vacuum.) When light changes speed as it moves from one medium to another, the direction in which it travels also changes.

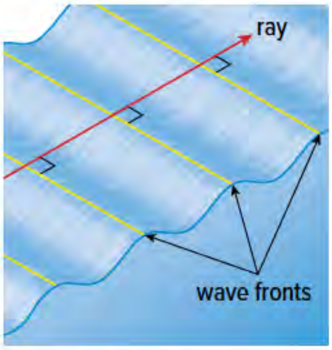


Figure 3.36 All the points on a wave front move together in the direction in which the wave itself is moving.

Describing Refraction Using the Wave Model and Ray Model of Light

It is helpful to use the wave model and ray model of light to visualize why the path of light changes direction when light changes speed. To see how these models fit together, look at Figure 3.36. Scientists often choose a specific part of a wave to follow and call it a *wave front*. As you can see in Figure 3.36, the crests of the waves are wave fronts. The ray (red arrow) shows the direction in which the waves are travelling. It is perpendicular to the wave fronts.

Try to visualize what happens when a wave front of light reaches the surface between two media. Imagine each wave front as a line of roller skaters holding hands. Figure 3.37A shows the movement of the skaters as they go from a paved surface to a gravel surface. As each skater reaches the gravel, he or she slows down. The slower skaters "pull" the line back and cause a bend in the line, representing the wave front. As a result, the direction in which the skaters move changes. This is what happens when a light wave moves from one medium to another: its speed and direction change (Figure 3.37B).

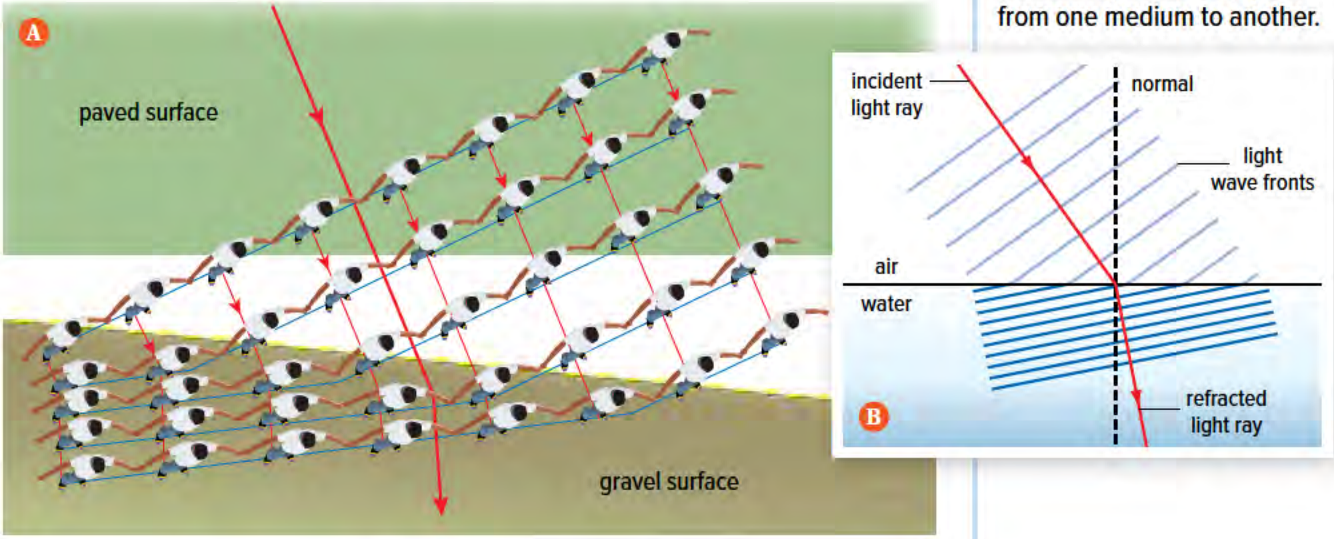


Figure 3.37 Ⓐ When some of the skaters slow down, the direction of the line changes. The larger red arrow shows the direction in which the skaters are moving. Ⓑ This visual shows how light waves behave in a similar way when they pass from one medium to another.

Did you notice that when the skaters and light waves slowed down, their direction turned toward the normal? When the speed of a wave slows down in the second medium, the direction of the wave is bent toward the normal. To predict if a wave will slow down or speed up when going from the first to the second medium, you need to know the density of the two media.

Light travels more slowly in a more dense medium than in a less dense medium. Therefore, the following statements are true.

- When light travels from a less dense to a more dense medium, the ray bends toward the normal.
- When light travels from a more dense medium to a less dense medium, the ray bends away from the normal.

Connect to Topic 2.2 on pages 114–115

Before you leave this page . . .

1. Come up with another analogy that you could use to visualize how refraction occurs.

CONCEPT 2

Light refracts as it passes through lenses.

Activity

Make a Simple Lens

1. Obtain a 10 cm by 10 cm piece of transparent material, a sheet of newspaper, a medicine dropper, and some water. Lay the transparent material on the newspaper. Place one drop of water on the transparent material. Observe the shape of the water drop.
2. Choose a word on the newspaper. Place the drop of water over it. Compare how the word looks through the drop and without it.
3. Add three more drops to the first drop of water. Observe the shape of the water drop. Then observe the word through the larger amount of water.
4. When you are finished, answer the questions below.
   a) How did the single drop of water affect the appearance of the word?
   b) How did the effect in step 2 compare with the one in step 3?
   c) How do you think the shape of the water drop affected the word's appearance?

lens a transparent object that causes light to refract and has at least one curved side

A **lens** is a transparent object that causes light to refract and has at least one curved side. Lenses come in a wide variety of sizes and shapes and are made of different types of materials (Figure 3.38).

Two Types of Lenses: Converging and Diverging

The terms plane, concave, and convex are used to describe lenses as well as mirrors, but lenses have two sides. Either side can be plane, concave, or convex, but at least one side must be curved. All lenses fit into one of two categories. They are either converging lenses or diverging lenses.

Figure 3.38 These lenses are made of glass, plastic, and even liquid.

Converging Lenses

Converging lenses bring parallel light rays toward a common point. Converging lenses have one or two convex surfaces. They are thicker in the centre. Figure 3.39 shows how parallel rays are brought together by a lens that is convex on both sides.

converging lens a lens that brings parallel light rays toward a common point

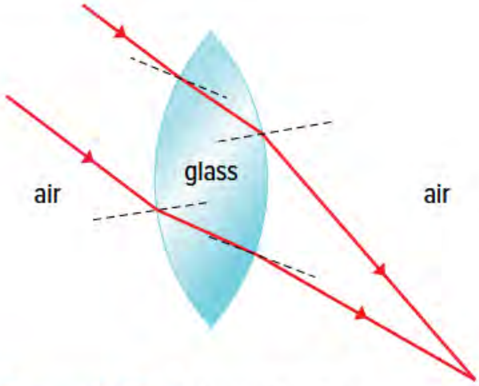


Figure 3.39 A converging lens

When rays strike the left side of the lens, they move from a less dense medium (air) to a more dense medium (the material that forms the lens). The rays refract toward the normals. This causes them to converge slightly.

When the light rays leave the lens, they move from a more dense medium to a less dense medium. When they do this, they refract away from the normals. At first, it might seem that this would cause the rays to separate. However, because of the overall shape of the lens, the final result is that the rays converge after passing through the lens.

Diverging Lenses

Diverging lenses cause parallel rays to spread away from a common point. Diverging lenses have one or two concave surfaces. They are thinner in the centre than on the edges. Figure 3.40 shows how parallel light rays refract when they enter and leave a lens that is concave on both sides.

diverging lens a lens that spreads parallel light rays away from a common point

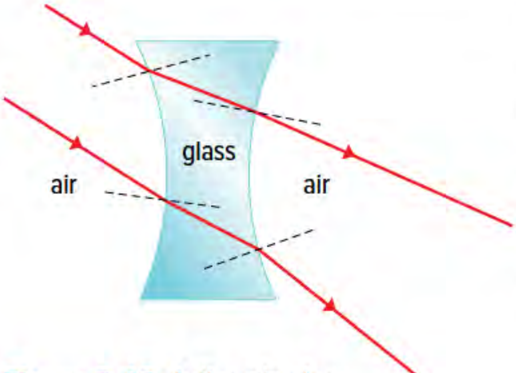


Figure 3.40 A diverging lens

When rays strike the left side of the lens, they move from a less dense medium (air) to a more dense medium (the material that forms the lens). This means that the rays refract toward the normals. Due to the curvature of the surface, the rays diverge slightly.

When the light rays leave the lens, they move from a more dense medium to a less dense medium. When they do this, they refract away from the normals. Because of the overall shape of the lens, the final result is that the rays diverge.

Before you leave this page . . .

1. What characteristic makes one lens converging and another diverging?

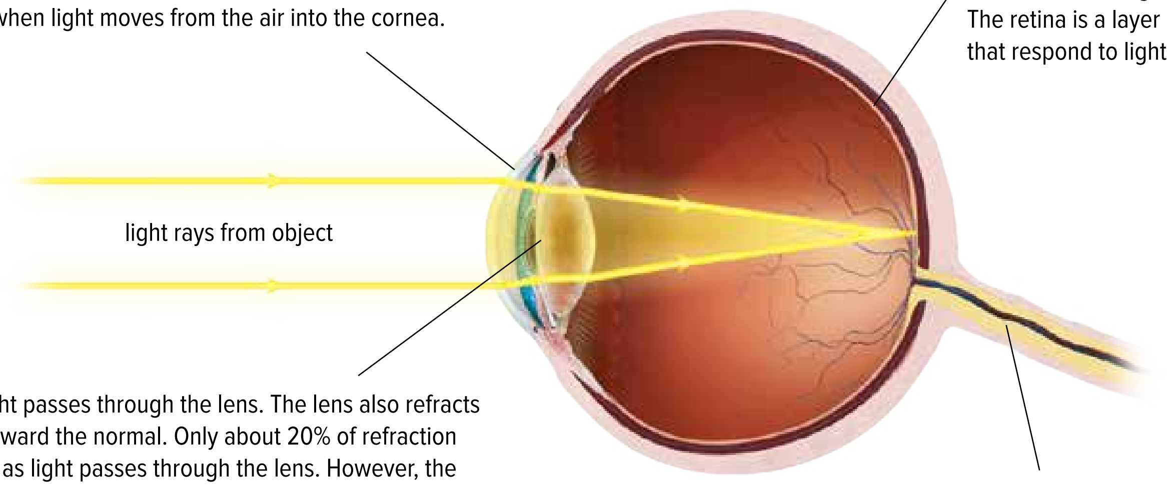
CONCEPT 3

Refraction plays a role in human vision.

The human eye can focus on objects at different distances and form images more accurately than a camera. However, none of this would occur without refraction. It is refraction that makes image formation in the eye possible.

The Front of the Eye Refracts Light

Refraction and focusing take place at the front of the eye. The refracted light forms an image at the back of the eye. The brain interprets the image. Follow the yellow rays in **Figure 3.41** to see what happens as light travels from an object or light source through the eye. Notice how light is refracted more than once before it strikes the back of the eye.



Light travels in a straight line from an object or source to the eye. It first travels through the cornea. The *cornea* is a lens in the front of the eye. Light travels from a less dense medium (air) to a more dense one (the cornea). As a result, the path of light bends toward the normal. About 80% of refraction takes place when light moves from the air into the cornea.

The light strikes the back of the eye, called the retina, and forms an image there. The retina is a layer of cells that respond to light.

light rays from object

The light passes through the lens. The lens also refracts light toward the normal. Only about 20% of refraction occurs as light passes through the lens. However, the lens is responsible for focusing on close objects.

Cells in the retina send nerve impulses to the brain through the optic nerve. The brain interprets the impulses as sight.

Figure 3.41 This diagram shows the path of light from a source or object through the human eye.

Figure 3.42 shows how the lens in the eye focuses on near and distant objects. A circular muscle that goes around the lens contracts and relaxes to change the shape of the lens. This lets the lens refract light to a different extent and focus light from both near and distant objects on the retina.

Connect to Investigation 3-I on page 258

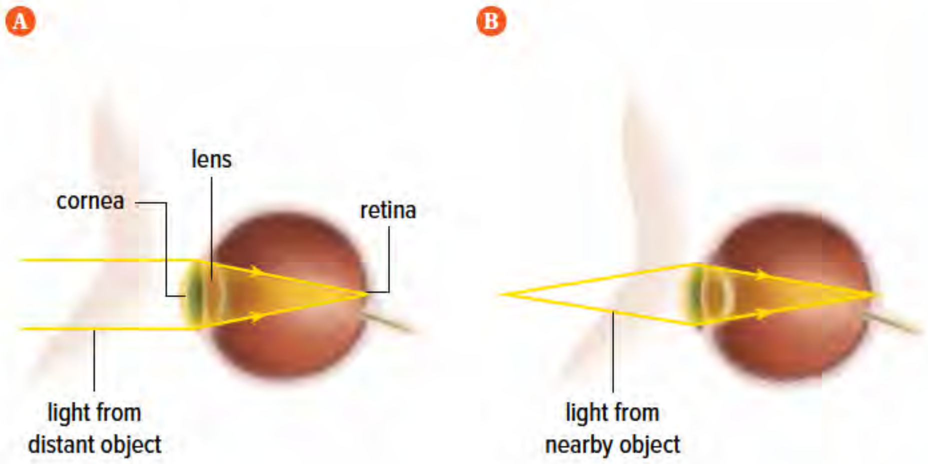


Figure 3.42 In Ⓐ, the muscle that goes around the lens is relaxed. The lens retains its normal shape. It focuses a distant object correctly on the retina. In Ⓑ, the muscle is contracted. This make the lens shorter and thicker. It becomes more curved to focus nearby objects.

Extending the Connections

The Back of the Eye Absorbs Light

The retina is a layer of cells that respond to light. It contains two types of cells that absorb incoming light. How are these cells involved in human vision? What roles do they play in vision problems such as red-green colour-blindness?

Before you leave this page . . .

1. Explain how the lens can focus images of both distant objects and nearby objects on the retina.
2. As a person ages, the lenses of the eyes become stiff. The muscles around the lenses can no longer make them change shape. How might this affect a person's vision?

CONCEPT 4

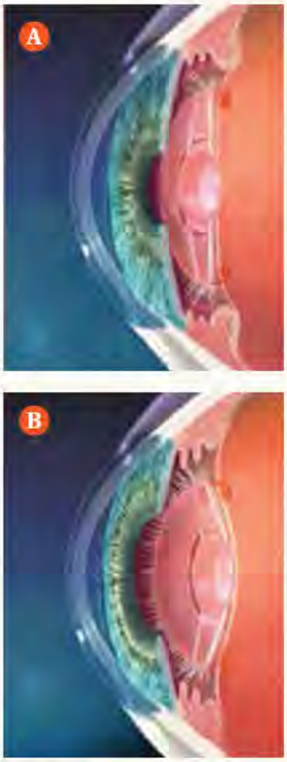
Many technologies take advantage of light's behaviour when it moves from one medium to another.

Activity

Modelling Cataracts

1. Your teacher will provide you with a pair of safety glasses and Parafilm tape. Cover the glasses with the Parafilm tape and put them on. How do the glasses affect your vision?
2. Your teacher will assign you a series of tasks to complete while wearing the glasses. How do the glasses affect your ability to complete the tasks?
3. Find out more about the risks and benefits of cataract surgery. Based on your experience in this activity, would you choose to have the surgery? Why or why not?

Technology has taken advantage of the refraction of light since the first lenses were constructed over a thousand years ago. A few modern technologies in which refraction plays an important role are described here.



Artificial Lenses

A cataract is the clouding of the lens of the eye. Cataracts usually occur after age 40. However, they can occur at a much younger age, and even in infants and children. When cataracts affect a person's vision, a surgeon can remove the cloudy lenses and insert artificial ones. Artificial lenses cannot change shape like natural lenses. This means the eye can only focus on distant objects. However, new artificial lenses are being developed. One is shown on the left. When the circular muscle around the lens relaxes Ⓐ, the eye focuses on distant objects. When the muscle contracts, it presses on the lens. Hinges in the lens bend Ⓑ, moving the lens back slightly. The eye focuses on objects at arm's length. The person will probably still need glasses to focus on close objects.

Heads-Up Display

A heads-up display or HUD refracts light from a projector through a prism. This makes an image (a computer display) appear in front of the user's eyes. The image appears as an overlay that hovers over the user's view of the real world. One application of a HUD is wearable head gear. This tool is used by pilots, scuba divers, alpine skiers, and others who benefit from its visual display. Users can check important information like speed, distance, depth, and altitude without taking their eyes from the view in front of them. Imagine snowboarding down a slope at Whistler and knowing your speed, altitude, and even direction—all without taking your eyes off the run!

Wavefront Technology

Wavefront technology was first developed to find irregularities in mirrors and lenses in telescopes. Today, eye doctors use it to map irregularities in the cornea and lens. Wavefront technology tracks how a wave front of visible light refracts as it passes through the eye. A machine called a wavefront analyzer directs light waves into a patient's eyes. Then it measures how the waves travel back through the eye and out of the pupil after they bounce off the retina. Wavefront technology helps doctors perform laser eye surgery. It is also used to diagnose and measure vision problems. Wavefront technology may one day make eye chart tests a thing of the past.

Extending the Connections

Beyond Human Vision

Binoculars, microscopes, digital SLR cameras, and some telescopes—these are technologies that enhance human vision in some way. Did you know they all rely on refraction? Choose one of these devices and find out how.

Before you leave this page . . .

1. Describe how new artificial lenses may allow people to see better.
2. Why do you think wavefront technology is an improvement over eye tests that use traditional eye charts?
3. Suggest another use for a HUD.

TAKE Action

Make a Difference

How Can You Help Bring Better Vision to the World?

Giving a person sight is an incredible gift. It's even more incredible if the gift comes right to you in the form of the Flying Eye Hospital. Many people in developing nations have had their vision improved or restored in just this way. The Flying Eye Hospital looks like your average airplane, but it's actually home to a mobile eye hospital and teaching centre. The gift of sight isn't just given to each patient. Its effects also spill over into the patient's family and community to change many lives for the better.

Third World Eye Care Society Canada (TWECS) is another organization that is helping people see in developing nations. The B.C.-based group distributes old eyeglasses to people in countries where poverty or lack of eye care services results in great need. The group also runs eye care projects. Eye doctors, opticians, and other volunteers all play a role in restoring vision through this organization.

Evaluate and Communicate

1. You can help people with vision problems right here in B.C. For example, CNIB runs local volunteer programs. Find out how volunteers are making a difference for visually impaired people in B.C.
2. Some organizations have stories on their websites in which volunteers describe their experiences. Write your own volunteer story that describes how you have made or would like to make a difference in your community as a volunteer.

Apply and Innovate

3. Create a plan to collect old eyeglasses in your community and get them to people who need them. Write down any questions that develop as you create your plan, and try to answer them. Then share your plan with your class. If you like, carry out your plan.

Check Your Understanding of **Topic 3.5**

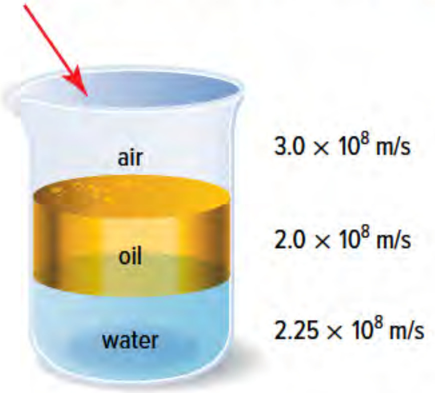
QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Draw a labelled diagram to show how the human eye senses light from a source. PA

2. Explain how vision depends on reflection, refraction, absorption, and transmission of light. PA AI

3. The diagram shows a beaker of cooking oil and water with a light ray about to enter the oil. The speed of light for the three media are shown beside the beaker. PC PA



   a) Use the information on the speed of light to rank the three media in terms of density. Explain why you ranked each medium as you did.

   b) Based on your answers to part a), explain how the path of light changes as it moves from one medium to the next.

4. Is the statement below true or false? Justify your response. PA E

   Light can travel across the boundary between two media without refracting if both media have the same density.

5. Society has benefited from the development of a range of vision-related devices and technologies. Describe two examples that take advantage of refraction. AI C

Connecting Ideas

6. Diverging lenses are needed to correct for nearsightedness, but the front of the eyeglasses is convex. How can a lens have one convex side but still be a diverging lens? Use a sketch to show your reasoning. (Hint: Reread the paragraph on diverging lenses.) E AI C

Making New Connections

7. Photovoltaic cells convert solar energy into electrical energy. How could the efficiency of photovoltaic cells be increased by using lenses? Use a diagram to support your answer. PA AI E C

8. HUDs can provide useful information in a very convenient way. QP PA AI E

   a) Describe how a HUD could help you carry out a task in your daily life.

   b) Predict a possible negative consequence associated with this technology.

9. Scientists believe that the eye of a living colossal squid is larger than a soccer ball. This makes the squid eye about 100 times larger than a human eye. The colossal squid lives near Antarctica, at a depth of at least 1000 m. Suggest how having such a large eye could help this giant thrive in the dark ocean depths. PA AI

INVESTIGATION

3-1

STRUCTURED INQUIRY AND GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Be careful not to drop the lenses.
- Do not touch the light source. It may be hot.
- Do not shine light directly into anyone's eyes.

What You Need

- variety of lenses
- projector
- screen
- ruler or measuring tape

Exploring Vision Problems

Refraction plays a role in correcting vision problems.

Question

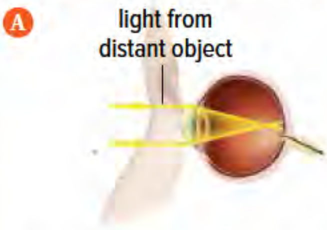
How can you correct vision problems?

Procedure: Part A—Structured

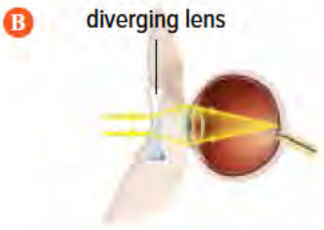
1. Read the information about vision problems below.

Most people with poor vision have *refractive errors*. When light is refracted by the eye, it does not form a clear image on the retina. Two common refractive errors are myopia and hyperopia.

Myopia (nearsightedness): Inability to focus on distant objects.

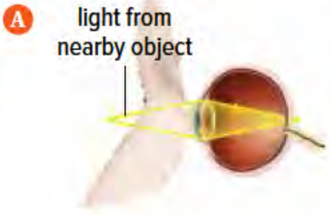


Myopia: The cornea and lens refract light from a distant object. The rays converge to form an image, but the eyeball is too long and the image forms in front of the retina. The rays have spread out again when they reach the retina, so the image is blurry.

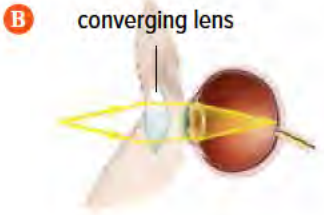


Myopia after corrective lenses: A diverging lens spreads out the rays before they reach the cornea. When the eye refracts the light, the image falls on the retina.

Hyperopia (farsightedness): Inability to focus on nearby objects.



Hyperopia: The cornea and eye lens refract light from a nearby object, but the eyeball is too short. The rays reach the retina before they meet, so the image is blurry.



Hyperopia after corrective lenses: A converging lens brings the rays closer together before they reach the cornea. When the eye refracts the light, the image falls on the retina.

2. Two patients are visiting an optometrist. (An optometrist is trained to diagnose and prescribe lenses for vision problems.) For each patient, use the information in step 1 to
   - a) identify the vision problem
   - b) explain the cause of the problem
   - c) describe what the light rays are doing in the patient's eyes (assume each eye has the same problem)
   - d) recommend the type of lens that would help correct the problem

   Patient 1: A 56-year-old female is having trouble reading books. She plays violin and has no problem reading the sheet music on her music stand.

   Patient 2: A 14-year-old male is having problems reading digital white boards at school. He also has trouble seeing the ball when playing lacrosse.

3. Laser surgery can change the curvature of the cornea to correct for refractive errors. Should the curvature of the cornea be increased or decreased for

   a) hyperopia? b) myopia?

   Explain your reasoning.

Procedure: Part B—Guided

4. You have access to several different lenses, a screen, and a projector. The projector will be out of focus, representing a refractive error.
   - a) Draw a sketch of a cross-section of each lens that shows how light rays refract as they pass through the lens.
   - b) Identify each lens as converging or diverging.
5. Use the lenses to form a clear image on the screen. You can adjust the distance between the lens and screen.
6. Draw a sketch of each image you produce under the sketch you made of that lens in step 4.
7. For each lens, measure and record the distance between the lens and the screen that produced the clearest image.

Process and Analyze

1. In Part A, what might be another explanation for the condition that Patient 1 is experiencing?
2. In Part B:
   - a) Which type of lens produced clear images when the distance between the lens and the screen was the shortest? What type of refractive error could the lens correct?
   - b) Which type of lens produced clear images when the distance between the lens and the screen was the longest? What type of refractive error could the lens correct?
   - c) Use the term refraction to explain your observations.

Apply

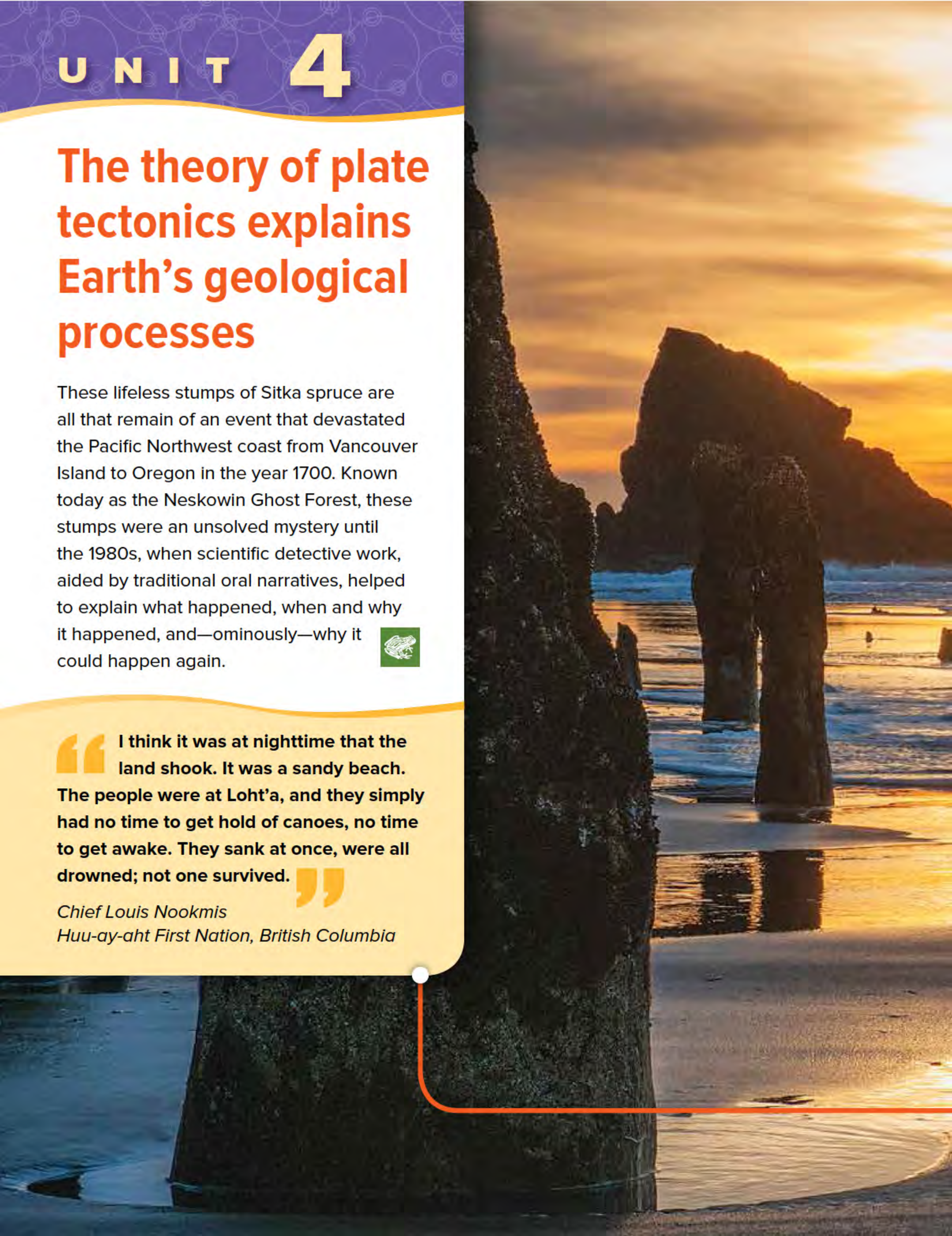
3. When you focus a digital SLR camera, you change the distance between the lens and the charge-coupled device (CCD), the light-sensitive part of the camera. In the human eye, the distance between the lens and the retina is fixed. How do the muscles in your eye accomplish the same result that the camera does by moving the lens?

UNIT 4

The theory of plate tectonics explains Earth's geological processes

These lifeless stumps of Sitka spruce are all that remain of an event that devastated the Pacific Northwest coast from Vancouver Island to Oregon in the year 1700. Known today as the Neskowin Ghost Forest, these stumps were an unsolved mystery until the 1980s, when scientific detective work, aided by traditional oral narratives, helped to explain what happened, when and why it happened, and—ominously—why it could happen again.

> **“I think it was at nighttime that the land shook. It was a sandy beach. The people were at Loht'a, and they simply had no time to get hold of canoes, no time to get awake. They sank at once, were all drowned; not one survived.”**
>
> *Chief Louis Nookmis*
> *Huu-ay-aht First Nation, British Columbia*



- What kinds of events could destroy a village and a forest so suddenly?
- What questions do you have about—this photo? the introduction? the quotation? the title for this unit? ...?

UNIT 4

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations to explore and represent Earth's tectonic plates, their movement, and Earth's composition
- Develop and use models and other methods to construct evidence-based explanations for how geological processes have changed and continue to change Earth's surface
- Seek patterns and connections to describe and explain geological events in our local, provincial, national, and global surroundings
- Use scientific understandings, First Peoples perspectives, and other ways of knowing to interpret geological processes in the past and present, and to make predictions about the future

ESSENTIAL QUESTION

How did we develop a unifying theory to explain Earth's geological processes?

Ridge Flank (-2
> Broadband Seismometer
> Current Meter
> Pressure Sensor
Endeavour Field (-2192 m)
Access Sampler
-mini
> Temperature Logger Chains
> Short Period Seismomter
> Bottom Pressure Recorder
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TOPIC 4.1:

What ideas, observations, and evidence led to the theory of plate tectonics?

Some things you will do:

- collaboratively plan and conduct investigations to answer questions about geological processes
- seek patterns and connections in data from your own investigations and secondary sources
- demonstrate an understanding and appreciation of evidence

Some things you will come to know:

- the connections among earthquakes, volcanoes, and mountains
- how scientists infer the composition of Earth's interior
- the evidence from multiple sources and over spans of time that supported the development of a theory of plate tectonics

TOPIC 4.2:

What are tectonic plates and how is their movement linked to geological processes?

Some things you will do:

- use a range of methods to represent patterns and relationships in data
- demonstrate an understanding and appreciation of evidence
- use scientific understandings to identify relationships and draw conclusions

Some things you will come to know:

- where Earth's tectonic plates are located, ways they move in relation to each other, and the geological activities associated with their movement
- a model that can be used to describe how plates move

TOPIC 4.3:

How does the theory of plate tectonics explain Earth's geological processes?

Some things you will do:

- demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest
- consider First Peoples perspectives and knowledge and other ways of knowing as sources of information
- co-operatively design a seismograph
- observe and measure and record data using your seismograph
- express and reflect on a variety of experiences and perspectives of place

Some things you will come to know:

- how and where earthquakes and volcanoes occur
- how the intensity of earthquakes is measured and communicated
- ways that mountains can form

TOPIC 4.4:

How do geological features and processes affect where and how we live?

Some things you will do:

- identify a question to answer or a problem to solve through scientific inquiry
- consider social, ethical, and environmental implications of the findings from your own and others' investigations
- generate and introduce new or refined ideas when problem solving
- consider First Peoples perspectives and knowledge and other ways of knowing as sources of information
- express and reflect on a variety of experiences and perspectives of place

Some things you will come to know:

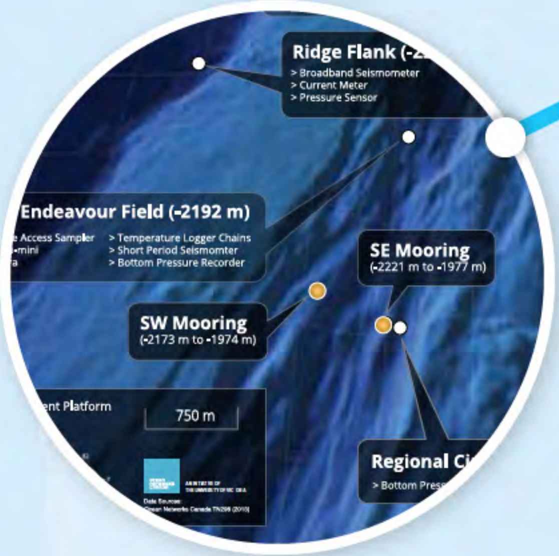
- the influence of place on personal and cultural identity, the establishment of communities, and factors that contribute to the economic health of communities
- ways that we use our knowledge and understanding of geological processes to keep safe

UNIT 4

Summary

ESSENTIAL QUESTION

How did we develop a unifying theory to explain Earth's geological processes?


Ridge Flank (-2
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SE Mooring
(-2221 m to -1977 m)
SW Mooring
(-2173 m to -1974 m)
ent Platform
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> Bottom Pres
Data Sources:
Ocean Networks Canada TN296 (2010)

TOPIC 4.1:

What ideas, observations, and evidence led to the theory of plate tectonics?

- Scientists debated how to interpret the shapes and positions of Earth's continents.
- Technology helps scientists make inferences about the different layers of Earth.
- Studies of the ocean floor revealed where new rock is made.
- The theory of plate tectonics provides a unified explanation for geological features and processes.

Key Terms

mid-ocean ridges
sea floor spreading
trenches
theory of plate tectonics

TOPIC 4.2:
What are tectonic plates and how is their movement linked to geological processes?

- Earth's surface is made of huge rocky plates.
- Tectonic plates move relative to each other, causing certain geologic activities.
- Mantle convection contributes to tectonic plate movement.

Key Terms

tectonic plates
convergent plate boundary
mantle convection
divergent plate boundary
transform plate boundary
ridge push
slab pull

TOPIC 4.3:
How does the theory of plate tectonics explain Earth's geological processes?

- Most earthquakes occur near tectonic plate boundaries.
- Movement along faults produces seismic waves.
- Most volcanoes occur where oceanic crust collides with another plate.
- Mountain ranges can also form when continental crust collides.

Key Terms

earthquake
seismic wave
magnitude
fault
epicentre
volcano
focus
seismographs

TOPIC 4.4:
How do geological features and processes affect where and how we live?

- The geological history of British Columbia helps shape our lives.
- We use our knowledge of geological processes to help keep us safe.

Key Terms

geohazard

UNIT 4

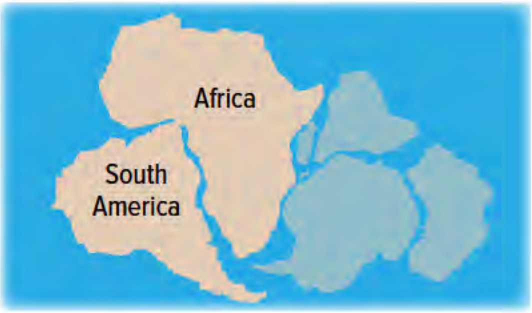
Review

What Do You Know?

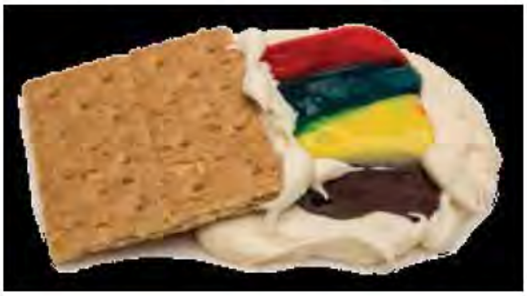
Connecting to Concepts

Visualizing Ideas

1. How does the image below relate to the continental drift hypothesis?



2. A teacher used cake frosting, Fruit Roll-Ups®, and graham crackers to demonstrate plate tectonics. The photo below shows one concept that the teacher demonstrated.



   a) What geologic feature does each of the following represent? Explain your answer for each.
      - the graham cracker
      - the Fruit Roll—Up
      - the cake frosting

   b) What process was the teacher demonstrating? How do you know?

3. There is a continent named Africa and a tectonic plate named the African plate.

   a) In what ways are they similar? In what ways are they different?

   b) Sketch a diagram to show the relationship between the African continent and the African plate. In your diagram, label important geologic features that help show the difference between the two.

Using Key Terms

4. Use a labelled diagram to show how the energy of an earthquake travels from the focus to the epicentre.

5. Develop a diagram that shows each of the following layers of Earth. Make sure each of the terms appears as a label in your diagram.
   - continental crust
   - upper mantle
   - outer core
   - asthenosphere
   - oceanic crust
   - lower mantle
   - inner core
   - lithosphere

Communicating Concepts

6. In this unit, you have learned about the continental drift hypothesis and the theory of plate tectonics.

   a) Describe two examples of evidence that supported the continental drift hypothesis. Are they direct or indirect evidence? Explain how you know.

   b) Describe two pieces of evidence that supported the theory of plate tectonics. Are they indirect or direct evidence? Explain how you know.

   c) Do you agree with the ideas presented in the theory of plate tectonics? Provide at least three reasons that support your opinion.

7. Draw a sketch that represents what happens when each of the following occurs. Name the type of plate boundary in each case.
   - a) a plate with continental crust collides with another plate with continental crust
   - b) a plate with oceanic crust collides with another plate with oceanic crust
   - c) a plate with oceanic crust collides with continental crust

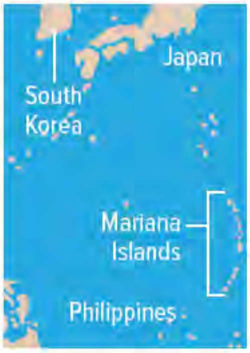
8. Wegener collected geologic and fossil evidence to support the idea that the continents may have once fit together in a supercontinent.
   - a) What do you think his reasons might have been for collecting this type of evidence?
   - b) Describe evidence that Wegener might have found that would have disproved the idea.
   - c) Why was Wegener's hypothesis rejected? If you were a scientist at that time, would you have rejected the hypothesis? Why or why not?

9. What evidence can scientists collect and refer to when determining whether an earthquake has occurred? Include both qualitative and quantitative evidence in support of your answer.

10. Sketch a diagram that shows each of the following.
    - mantle convection
    - slab pull
    - ridge push
    - a) Describe what occurs in each process.
    - b) How do these processes support the theory of plate tectonics?

11. What is a geohazard?
    - a) Name an example of a geohazard that exists in B.C.
    - b) Describe social and economic impacts that the geohazard in part a) can have on the area where it happens.
    - c) Describe two actions people can take to reduce the risk or effect of this geohazard.

12. The Mariana Islands in the North Pacific Ocean are an example of a volcanic island arc. Describe how they formed according to the theory of plate tectonics.



What Do You Know?
Connecting to Competencies

Developing Skills

13. Scientists often must rely on both direct and indirect evidence when investigating different phenomena.
    - a) What do the terms "direct evidence" and "indirect evidence" mean? Give an example of each that you have learned about in this unit and also in a subject other than earth science.
    - b) How do you think the type of investigation and what is being investigated influences how much scientists must rely on indirect evidence?

Thinking Critically and Creatively

14. Do you agree or disagree with the following statement? "Mountain ranges are only produced from the collision between tectonic plates." Be sure to support your answer.

Unit 4 Review *(continued)*

15. An opinion editorial, or op-ed, is an essay of the writer's thoughts about an issue. Op-eds are often written to raise awareness about a topic. Write an op-ed on one of the following topics, or choose one of your own that is related to the topics covered in this unit. The article should be one or two paragraphs long. Use your scientific knowledge to support your opinion.

- Providing money to study the plate tectonic activity near the coast of B.C., with the aim of being able to predict when a large and devastating earthquake will occur. Is this a proper use of funds?
- Providing money to upgrade older buildings, such as schools and hospitals, to make them more earthquake proof. Is this a fair use of funds when it is only for certain regions of the province?
- Covering the cost of rescuing people who remain in or enter areas of known danger due to geohazards such as earthquakes, avalanches, or landslides.

Understanding Big Ideas
Making New Connections

Applying Your Understanding

16. Is the following statement true or false? "The continual formation of new rock on the ocean floor means that Earth must be getting larger." Provide two reasons that support your answer.

17. The Burgess Shale is one of the most important fossil discoveries in the world. Fossil remains of organisms that once lived in ancient seas are found high up in the Canadian Rockies of B.C. within Yoho and Kootenay National Parks. Using your knowledge of plate tectonics, describe how fossils of these organisms could end up on mountain tops.

Thinking Critically and Creatively

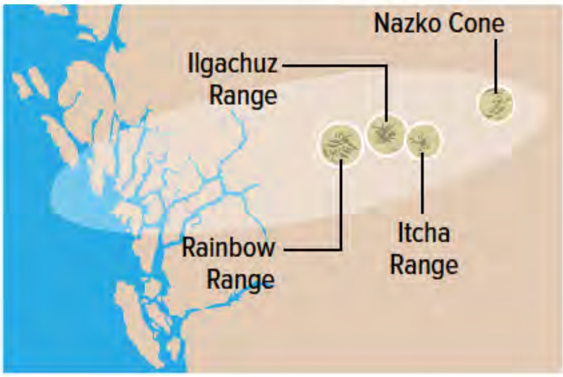
18. Do you think Pangaea could have been the only supercontinent that ever existed on Earth? Explain why or why not. Describe evidence that would support or disprove this.

19. In this unit, you have learned about mantle convection. However, convection is an important part of other processes on Earth.

a) Describe what convection is.

b) Where else on Earth do you think it occurs? Explain how it occurs there and what effect it has.

20. Central B.C. is home to a volcanic hot spot called the Anahim hot spot. The Anahim Volcanic Belt is a 600-km-long line of volcanoes that runs just north of Vancouver Island to near Quesnel, B.C. The major volcanoes are shown in the map below. The Nazko Cone is the youngest and Rainbow Range is the oldest. What evidence could scientists collect to determine which of the volcanoes is youngest and which is oldest?



Connecting to Self and Society

21. Plan an imaginary field trip to a geologic feature that interests you or that you have visited previously. You need to organize all the parts of the trip. Some things to find out include the following:

- You will also be a guide for the trip, so you need to perform research on the geologic feature, and be able to describe your relationship to the feature (why you chose it, what type of connection you have with it).
- What needs to be done to arrange the vehicle for travel? Will it be an overnight trip and will accommodations be needed?
- A breakdown of the cost of everything. Identify how the cost of the trip will be covered.

Collect the information in the form of a presentation of your choice. It could be a display of any type, a brochure, or even a website.

22. Create a script for a one minute commercial highlighting a geologic feature in B.C. that you think would be a great new place for tourists to visit. If your teacher allows, film the commercial using your script. Keep the following points in mind:

- The geological history of the feature
- Who you want your target audience to be
- What type of tourist destination you want to showcase it as—rugged and remote, or scenic and easily accessible by everyone, young and old

23. B.C. is one of the most popular tourist destinations in Canada.

a) What role do you think places like mountainous areas play in the economy? Describe types of businesses that may be involved.

b) Describe one or two negative effects of tourism in these areas.

24. The province strongly encourages all its citizens to be prepared for hazards that may occur in the region a person lives in.

a) It is common to hear people use words like “the Big One” and talk about “Earth being ripped open like a zipper” when referring to potential earthquakes in B.C. Why do you think such dramatic statements are made? Do you think it helps get people prepared? Why or why not?

b) Every year, Public Safety Canada works with provinces and territories to promote Emergency Preparedness Week, which runs during the first full week of May. In 2016, several areas hosted an earthquake simulator that people could enter and experience what a magnitude-8 earthquake would feel like. Why do you think such events are held?

25. Reflect on how your studies of science this year have helped you learn about yourself, your community, people elsewhere in your province and country, and the world as a whole. What understandings do you have now that you didn’t have before? What are three new things you would like to learn or inquire about, and why?

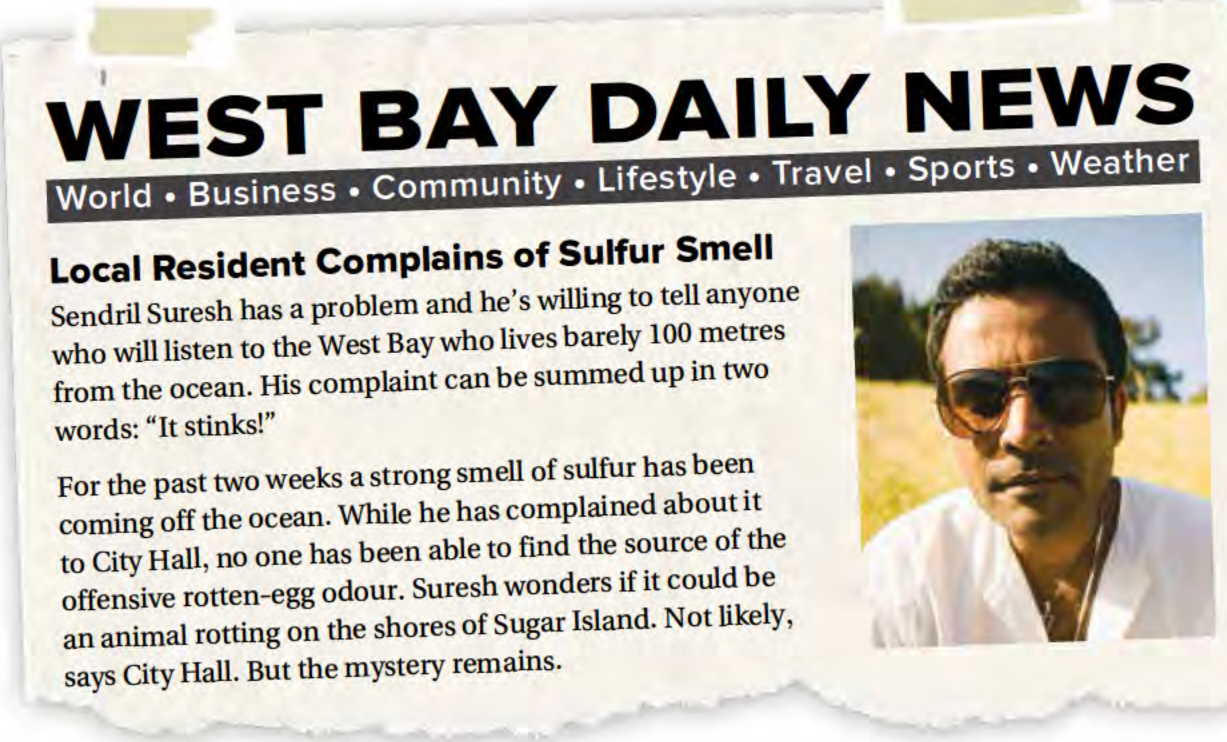
Unit Assessment

Trouble in West Bay?

For this task, you will collect, prioritize, and analyze evidence to decide the best course of action for the city of West Bay. West Bay is similar to any city along the coast of British Columbia.

Along with the information on these pages, your teacher will provide you with additional information. This may be in the form of handouts, videos, and audio files. Some of the information may be relevant to your task, and some may not. That is for you to decide.

Local Geological Events	Date	1712	1765	1802	1847	1891	1925	1963
West Bay Earthquakes	Magnitude	4.3	3.2	5.7	4.6	3.9	5.1	2.8



WEST BAY DAILY NEWS

World • Business • Community • Lifestyle • Travel • Sports • Weather

Local Resident Complains of Sulfur Smell

Sendril Suresh has a problem and he's willing to tell anyone who will listen to the West Bay who lives barely 100 metres from the ocean. His complaint can be summed up in two words: "It stinks!"

For the past two weeks a strong smell of sulfur has been coming off the ocean. While he has complained about it to City Hall, no one has been able to find the source of the offensive rotten-egg odour. Suresh wonders if it could be an animal rotting on the shores of Sugar Island. Not likely, says City Hall. But the mystery remains.

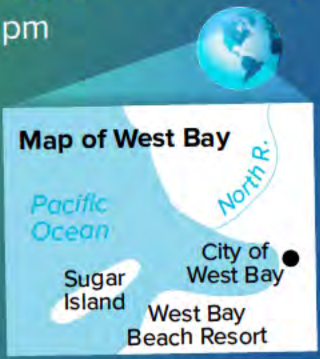
West Bay seismologists notice increase in earthquake activity

The Geological History of West Bay

Date: July 17 • Time: 8:00 pm

Presenter: Dr. Emily Cho

Dr. Cho will discuss various geological events, including earthquakes and volcanoes in the history of West Bay, and discuss the changes of a new earthquake in the next 25 years.



Road damage on Sugar Island just off the coast of West Bay

Career of the Month:

Seismologist – Dr. Emily Cho

What does a seismologist do?

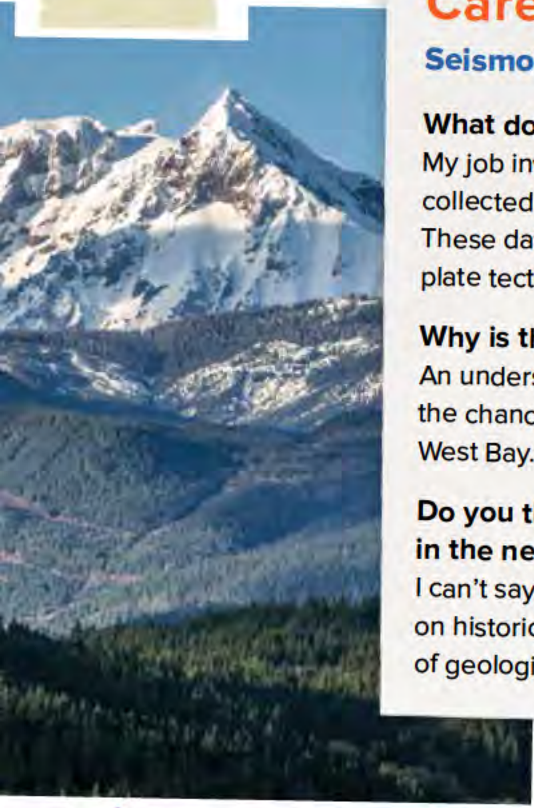
My job involves analyzing seismic data collected along the West Coast of Canada. These data can be used to help us understand plate tectonic movement in this area.

Why is this important?

An understanding of earthquake and volcanic activity allows us to better predict the chances of future geological events along the coast. of course, this includes West Bay.

Do you think we're in danger of an earthquake or volcanic eruption in the near future?

I can't say an earthquake or a volcano will happen at any given time, but based on historical evidence, I can say that we are overdue for some sort of geological event.



Dormant volcano Mount Garibaldi; could it ever come alive again?

Your Task

Your teacher will start the TimeStamp™ video when the task begins. Using your knowledge of plate tectonics, earthquakes, volcanoes, and mountain formation, predict what geological processes are occurring and what action local authorities should take.

TOPIC
4.1

What ideas, observations, and evidence led to the theory of plate tectonics?

Key Concepts

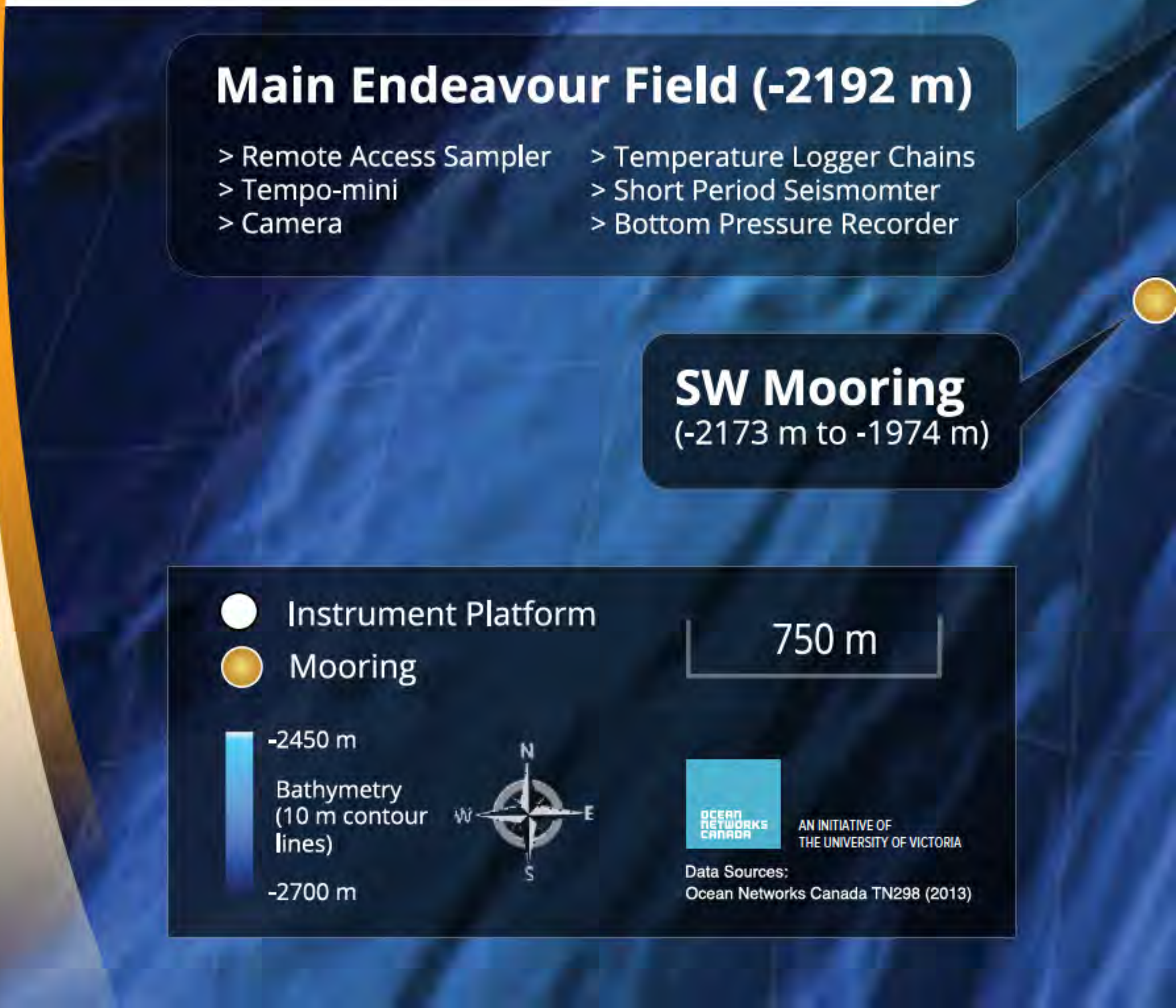
- Scientists debated how to interpret the shapes and positions of Earth's continents.
- Technology helps scientists make inferences about the different layers of Earth.
- Studies of the ocean floor revealed where new rock is made.
- The theory of plate tectonics provides a unified explanation for geological features and processes.

Curricular Competencies

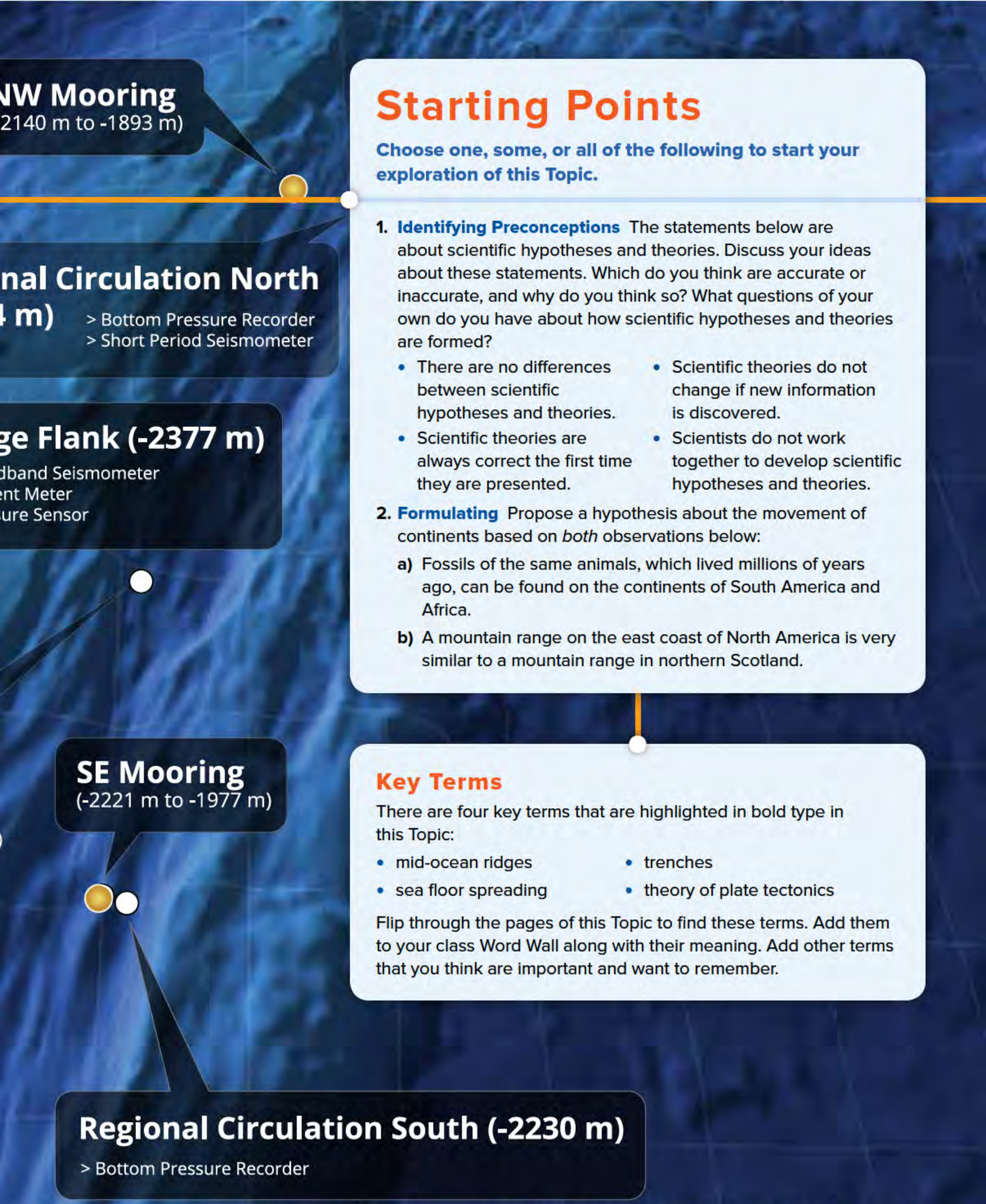
- Seek patterns and connections in observations.
- Use scientific understanding to draw conclusions.
- Transfer and apply learning to new situations.
- Apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information

Looking east from the Pacific coastline, you face a chain of mountains called the Coast Mountains. If you turn to face west, it's islands and water—water as far as the eye can see. But 300 km off the coast, and 2.2 km beneath the surface, lies another chain of mountains called the Juan de Fuca Ridge. Here, huge slabs of Earth's crust slowly move apart, and new ocean floor is forming. Ocean ridges like this exist elsewhere on Earth. These formations and the processes connected with them have shaped Earth's surface for millions of years, and they continue to do so today.

Scientists study areas of the ocean floor like the Juan de Fuca Ridge, shown here. They place instruments, such as seismometers, pressure sensors, and cameras, to monitor changes. The data they collect helps them to make predictions about where, and sometimes when, these geological processes may occur.


Main Endeavour Field (-2192 m)
> Remote Access Sampler
> Tempo-mini
> Camera
> Temperature Logger Chains
> Short Period Seismomter
> Bottom Pressure Recorder
SW Mooring
(-2173 m to -1974 m)
Instrument Platform
Mooring
750 m
-2450 m
Bathymetry
(10 m contour lines)
-2700 m
N
E
S
W
OCEAN NETWORKS CANADA
AN INITIATIVE OF THE UNIVERSITY OF VICTORIA

Data Sources:
Ocean Networks Canada TN298 (2013)


NW Mooring
2140 m to -1893 m)
nal Circulation North
m)
> Bottom Pressure Recorder
> Short Period Seismometer
ge Flank (-2377 m)
dband Seismometer
ent Meter
ure Sensor
SE Mooring
(-2221 m to -1977 m)
Regional Circulation South (-2230 m)
> Bottom Pressure Recorder

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The statements below are about scientific hypotheses and theories. Discuss your ideas about these statements. Which do you think are accurate or inaccurate, and why do you think so? What questions of your own do you have about how scientific hypotheses and theories are formed?
   - There are no differences between scientific hypotheses and theories.
   - Scientific theories are always correct the first time they are presented.
   - Scientific theories do not change if new information is discovered.
   - Scientists do not work together to develop scientific hypotheses and theories.
2. **Formulating** Propose a hypothesis about the movement of continents based on *both* observations below:
   a) Fossils of the same animals, which lived millions of years ago, can be found on the continents of South America and Africa.
   b) A mountain range on the east coast of North America is very similar to a mountain range in northern Scotland.

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- mid-ocean ridges
- sea floor spreading
- trenches
- theory of plate tectonics

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Scientists debated how to interpret the shapes and positions of Earth's continents.

Activity

Looking at Maps

Conduct brief research on maps from different time periods in history. What does the oldest known map show? What do maps from the 16th century show? How do they differ from maps from the 19th century (Figure 4.1)? What observations can you make about the position and shape of continents from modern-day maps?

Connect to Investigation 4-A on pages 284–285

With the exception of events such as earthquakes, volcanic eruptions, and landslides, most of Earth's surface appears to remain relatively unchanged during the course of a human lifetime. On a geologic time scale, however, Earth's surface has changed dramatically. Some of the first people to suggest that Earth's major features might have changed were early mapmakers. In the 1500s, mapmakers noticed that the edges of continents on either side of the Atlantic Ocean seemed to fit together, like pieces of a jigsaw puzzle. The world map shown in Figure 4.1 is one that was made in the 1800s. For hundreds of years scientists questioned how continents came to be in the configuration that they are today.

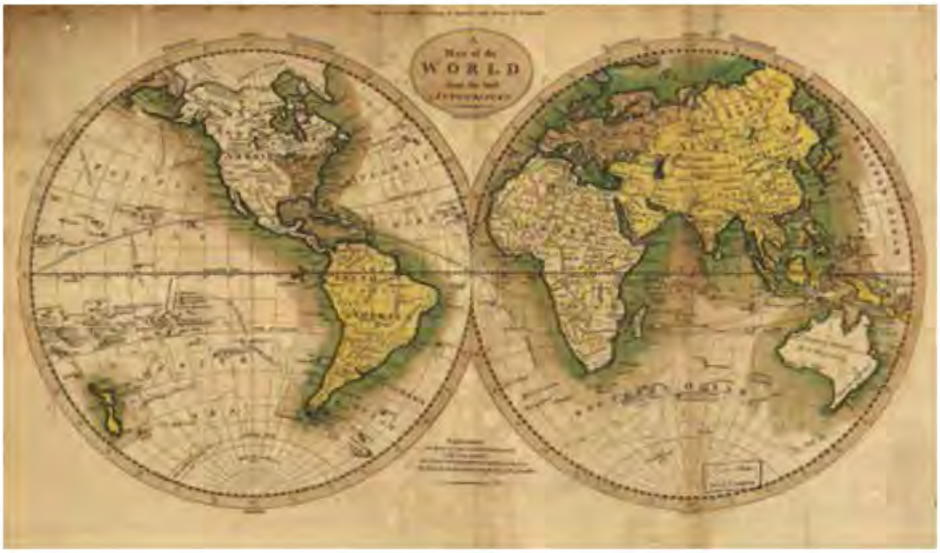
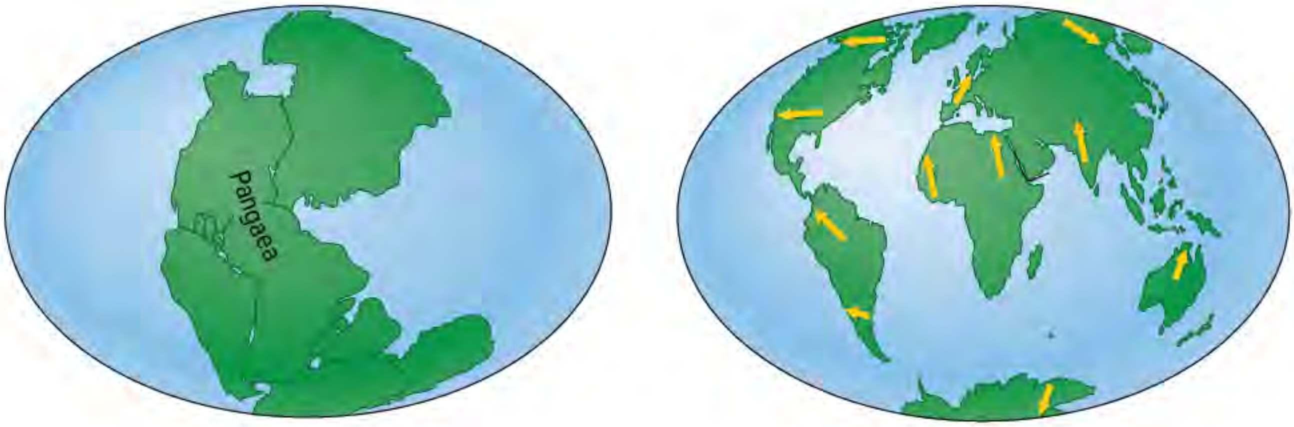


Figure 4.1 This map of the world was made in the 1800s. Which continents look like they might have once fit together?

Until the mid-1900s, most geologists thought that the locations of the continents and oceans were determined when Earth first formed. This idea, called *fixism*, assumes that the continents have been in the same locations since Earth first formed. However, after observing that some of the continents looked like they could fit together, some people wondered if Earth's continents were once joined together. A German scientist named Alfred Wegener also thought this and decided to investigate the possibility. He did research and collected rock, climate, and fossil information from around the world to see if he could find evidence to support the idea that the continents were once joined together. In 1912, Wegener presented his findings to the scientific community.

The Continental Drift Hypothesis

Based on the evidence he collected, Wegener proposed his *continental drift hypothesis*. Wegener created a new map of Earth by fitting the continents together. He suggested that about 200 million years ago all the continents were connected as a single supercontinent called Pangaea. In Greek *pan* means "all" and *gaea* means "world." Figure 4.2 shows the possible shape of Pangaea. Wegener hypothesized that over time, the continents slowly moved apart until they reached their current positions.



200 million years

Present

Figure 4.2 Wegener suggested that a supercontinent existed 200 million years ago. (Arrows in the right diagram indicate direction of movement.) **Draw a sketch that shows how the continents could get to their present locations from where they were 200 million years ago. Your sketch should show two or three stages of the process.**

Wegener's Hypothesis Is Rejected

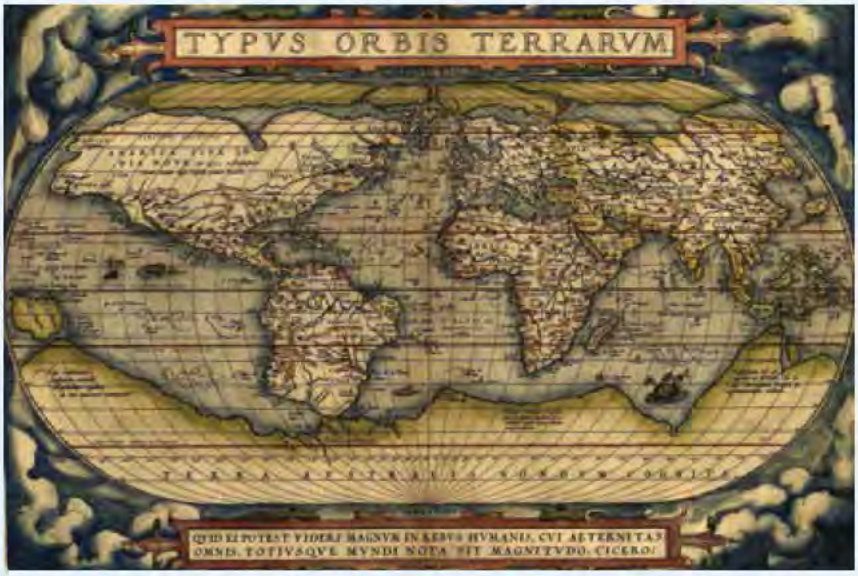
Even though Wegener's evidence supported the idea that the continents may have once been joined, most scientists strongly rejected his hypothesis. Wegener could not explain how continents could move. Also, scientists could not imagine what forces could be large enough to make a continent move.

Although Wegner's hypothesis was initially rejected, it was revisited decades later. Discoveries about the ocean floor provided information that supported the idea that continents move. His hypothesis is now seen as the start of the development of the theory of plate tectonics.

Activity

What Goes Into Making Maps?

The map below was drawn in the 1570s. Compare it with the map in Figure 4.1. Use digital and print resources to find other maps from the past. What assumptions about the world do you think map-makers have when they draw their maps? Is it possible to eliminate bias from a map? See if your class can reach a consensus on these questions.


TYPVS ORBIS TERRARVM
TERRA AVSTRALIS NONDVM COGNITA
QVID EI POTEST VIDERI MAGNVM IN REBVS HVMANIS, CVI AETERNITAS OMNIS, TOTIVSQVE MVNDI NOTA SIT MAGNITVDO. CICERO.

Before you leave this page . . .

1. In your own words, describe the continental drift hypothesis.
2. How did Wegener support his hypothesis? Why do you think he chose this type of information?
3. Why was the continental drift hypothesis rejected?

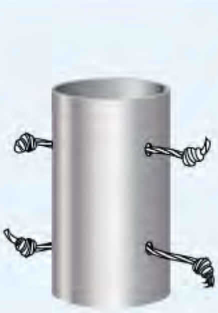
CONCEPT 2

Technology helps scientists make inferences about the different layers of Earth.

Activity

How Well Can You Describe What You Can't See?

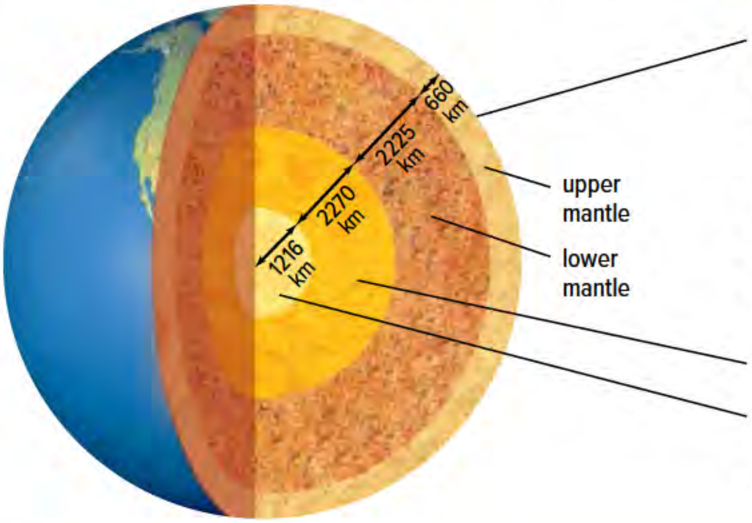
Your teacher will give your group a mystery tube like the one shown here. Your challenge is to figure out what the inside of the tube looks like—without opening the tube! Discuss, record, and try out all your ideas until you are confident in your solution.



Earth is about 12 700 km in diameter. This means there are about 6350 km between you and the centre. But no one has ever seen Earth's inner layers, and no tools can probe that deep. Since scientists cannot observe the interior directly, they use indirect evidence to model Earth's structure. One way is by studying energy waves that travel through the interior during earthquakes. The speed and behaviour of the waves are affected by the material they pass through. By studying the waves, scientists infer Earth's structure and composition (Figure 4.3).

Connect to Topic 2.4 on page 157

Figure 4.3 A model of Earth, showing its interior layers



crust: This is a thin layer of solid rock surrounding Earth. The crust is thinner under the oceans (oceanic crust) and thicker under the continents (continental crust). Oceanic crust is mostly basalt. Continental crust is mostly granite.

mantle: There is an upper and lower mantle. The top part of the upper mantle is solid. A part just below this is made of rock that is like soft taffy, so it can flow slowly. The rest of the upper mantle and the lower mantle are made of denser, more solid material.

outer core: The outer core is the only layer that is liquid.

inner core: Earth's deepest layer is also the hottest at more than 5000°C. It is solid because the very dense core material is under extreme pressure.

Before you leave this page . . .

1. In what way does the structure of Earth support the idea that continents can move?

CONCEPT 3

Studies of the ocean floor revealed where new rock is made.

Mountains and Trenches of the Ocean Floor

By the 1870s, scientists had begun to study and map the ocean floor using weighted ropes and piano wire dragged by ships. When contact was made with objects below the surface, the length of the ropes and wires was recorded. In the 1920s, ropes and wires were replaced with sonar—devices that send out sound waves and record the time for the waves to bounce back. This technology helped scientists discover and detail vast mountain ranges and deep valleys. These **mid-ocean ridges** and **trenches** are shown in Figure 4.4.

mid-ocean ridges mountain ridges along the ocean floor

trenches deep valleys in the ocean floor

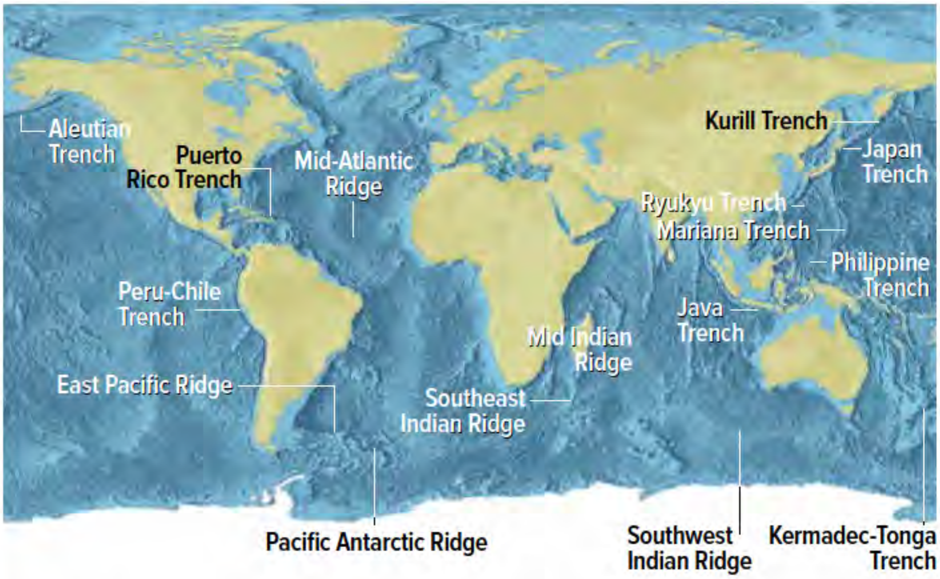

Aleutian Trench
Puerto Rico Trench
Mid-Atlantic Ridge
Kurill Trench
Japan Trench
Ryukyu Trench
Mariana Trench
Philippine Trench
Peru-Chile Trench
Java Trench
Mid Indian Ridge
East Pacific Ridge
Southeast Indian Ridge
Pacific Antarctic Ridge
Southwest Indian Ridge
Kermadec-Tonga Trench

Figure 4.4 The ocean floor consists of mid-ocean ridges and deep sea trenches. **What does the presence of mountain ranges on both land and on the ocean floor tell you about how they are formed?**

Mid-ocean ridges circle Earth and are nearly 60 000 km long. Some tower as high as 3 km above the ocean floor. The mid-Atlantic ridge, at 16 000 km long, is longer than any mountain range on land. Scientists also discovered that earthquakes and volcanic eruptions are common along mid-ocean ridges.

Deep sea trenches are long, narrow depressions in the ocean floor. They can be thousands of kilometres long and many kilometres deep. The Mariana Trench is more than 11 km deep. Compare this to Mount Everest, the world's tallest mountain, which is about 9 km above sea level. Figure 4.5 shows a few features of mid-ocean ridges and trenches that have been discovered.

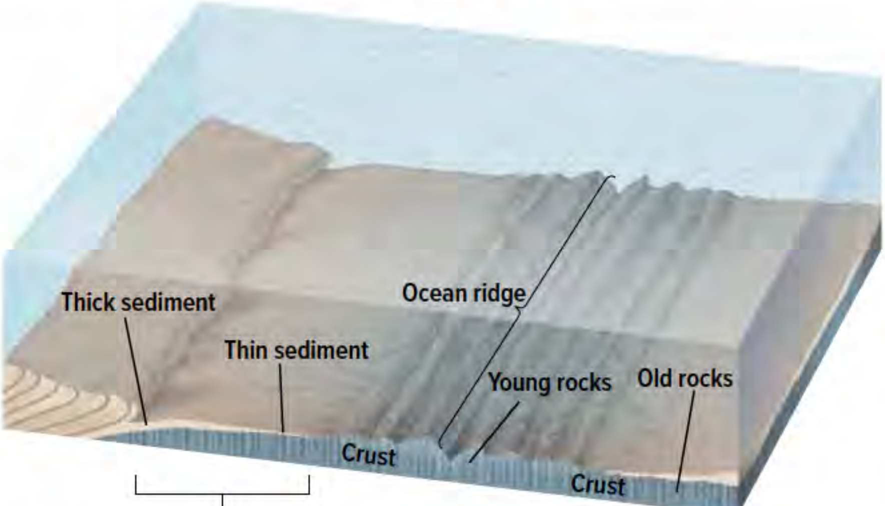
Extending the Connections

Sonar Reveals Hidden Haida Gwaii Village

Archeological excavations on Haida Gwaii have demonstrated that people lived there 12 700 years ago. But oral histories of First Peoples tell of a human presence there thousands of years earlier. Two archeologists with the University of Victoria, Quentin Mackie and Daryl Fedje, agree. And now, thanks to sonar technology, there is evidence that supports First Peoples Traditional Ecological Knowledge of the region. Find out about the discoveries that have been made off the east coast of Haida Gwaii.

Making New Rock on the Ocean Floor

In general, ocean rocks are much younger than land rocks. As well, the ocean floor near mid-ocean ridges is younger than ocean floor farther away from the ridges (Figure 4.5).



The layer of sediment that covers the ocean floor gets thicker as you move farther away from the mid-ocean ridge. This suggests the ocean floor is younger closer to the mid-ocean ridge.

Ocean rocks closer to a mid-ocean ridge are younger than ocean rocks farther from a ridge.

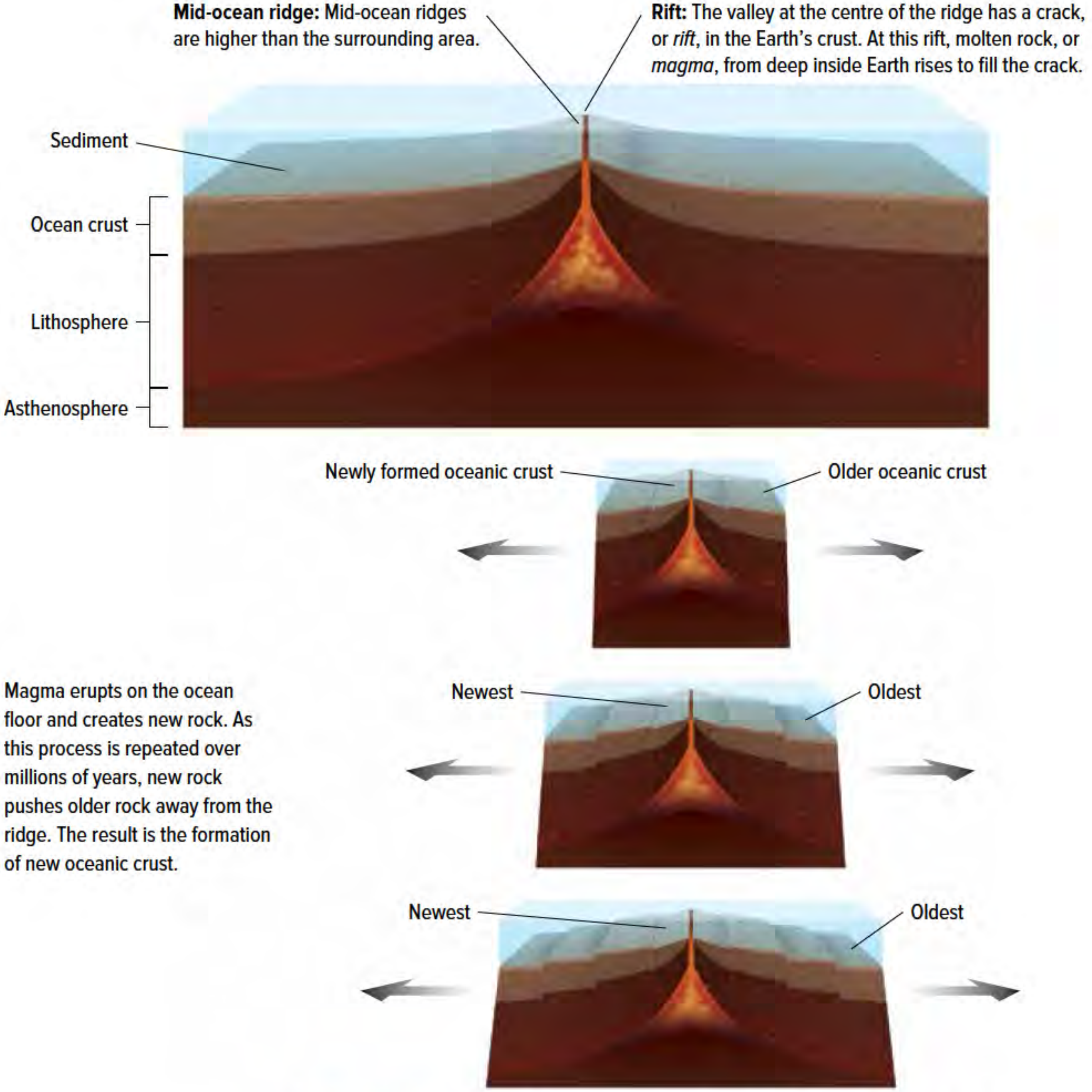
Figure 4.5 Ocean floor near mid-ocean ridges is younger than ocean floor farther away from mid-ocean ridges.

The ages of rocks at mid-ocean ridges puzzled many scientists. In 1962, a geologist named Harry Hess proposed an explanation. He suggested that new ocean crust is made at mid-ocean ridges. This process is called **sea floor spreading**, and it is described in Figure 4.6, on the next page.

The discovery of sea floor spreading was an important step to understanding how continents could move. Molten rock from a rift in a mid-ocean ridge cools, hardens, and continuously pushes older rock aside in the opposite direction on both sides of the ridge. Continents can be carried by the widening ocean floor in much the same way that objects are moved by a conveyer belt.

sea floor spreading process of magma rising to the surface at mid-ocean ridges to form new ocean crust

Connect to Investigation 4-B on page 286



Mid-ocean ridge: Mid-ocean ridges are higher than the surrounding area.

Rift: The valley at the centre of the ridge has a crack, or *rift*, in the Earth's crust. At this rift, molten rock, or *magma*, from deep inside Earth rises to fill the crack.

Magma erupts on the ocean floor and creates new rock. As this process is repeated over millions of years, new rock pushes older rock away from the ridge. The result is the formation of new oceanic crust.

Sediment
Ocean crust
Lithosphere
Asthenosphere
Newly formed oceanic crust
Older oceanic crust
Newest
Oldest
Newest
Oldest

Figure 4.6 Sea floor spreading explains how new oceanic crust is made. **Describe how the formation of new oceanic crust supports the idea that continents can move.**

Before you leave this page . . .

1. In two or three sentences, describe how the discoveries of mid-ocean ridges and the ages of ocean rock support the idea that the ocean floor is spreading apart.
2. Describe the process of sea floor spreading.

CONCEPT 4

The theory of plate tectonics provides a unified explanation for geological features and processes.

By the early 1960s, despite the evidence for sea floor spreading, many scientists were still unwilling to reject ideas about geological processes they had held for so long. But in the 1970s, small research submarines called ROVs (remote operated vehicles) were taking photos of the ocean floor. Now scientists could make direct observations of mid-ocean ridges and trenches. Now, for the first time, scientists had direct evidence of sea floor spreading.

As time passed, more and more evidence suggested that Wegener's original hypothesis had merit. A key feature that it lacked—a way to explain how continents could move—was now available. Eventually, scientists came to understand that Earth's surface is made up of huge slabs of rock called *tectonic plates* floating slowly on a layer of fluid-like rock in the mantle. The names and locations of these plates are shown in Figure 4.7. There are 12 major plates, and many smaller ones, that all fit together. The activity at mid-ocean ridges and trenches (Figure 4.8 on the next page) is related to how the boundaries (edges) of these plates interact. The theory that explains these and other of Earth's geological processes is called the **theory of plate tectonics**.

theory of plate tectonics the lithosphere is broken into large plates that interact and cause geologic activities

Figure 4.7 Earth's tectonic plates move very slowly—about 2.5 cm per year. This is about the same rate that your fingernails grow.

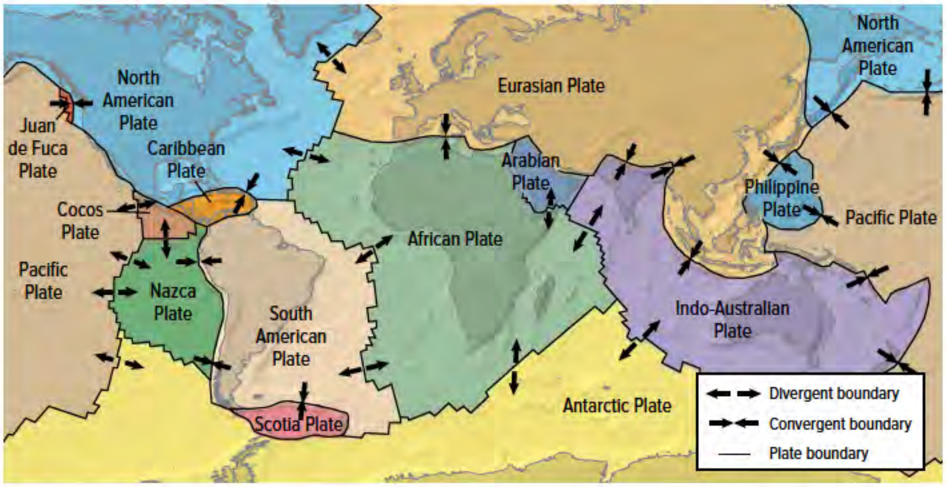
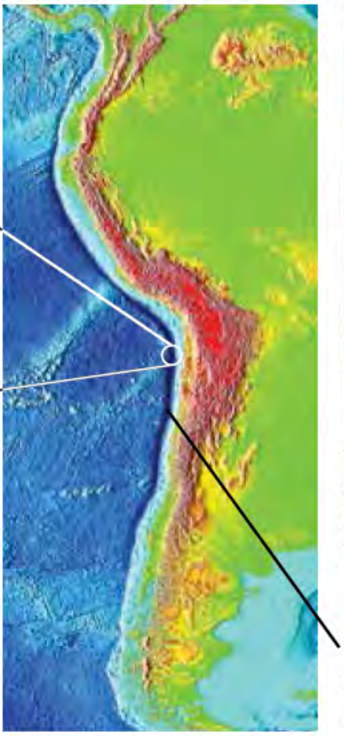

North American Plate
Juan de Fuca Plate
Caribbean Plate
Cocos Plate
Pacific Plate
Nazca Plate
South American Plate
Scotia Plate
African Plate
Eurasian Plate
Arabian Plate
Philippine Plate
Pacific Plate
North American Plate
Indo-Australian Plate
Antarctic Plate
Divergent boundary
Convergent boundary
Plate boundary

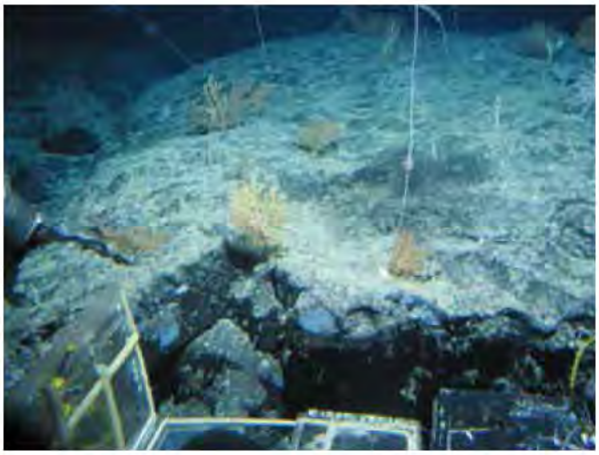
Figure 4.8 Examples of features of mid-ocean ridges and trenches

Scientists explore a mid-ocean ridge in submersible vehicles.

This snailfish, discovered in 2010 at a depth of 7000 m, is one of many unique organisms living in the Peru-Chile trench.



The Peru-Chile trench is 8000 m deep and 6000 km long. It formed when the Nazca plate was subducted under the South American plate.



A coral and sponge garden grows on the Kelvin Seamount, part of the New England Seamount Chain in the Atlantic Ocean.

Plate Tectonics—A Unifying Theory

The theory of plate tectonics explains many of the features and events that take place at and below Earth's surface. It explains how and why the continents move; how and why sea floor spreading occurs; and how, why, and where earthquakes, volcanoes, and the formation of mountains occur. It is a unifying theory, because it elegantly brings together (unifies) ideas and explanations from a wide array of scientific and other ways of knowing.

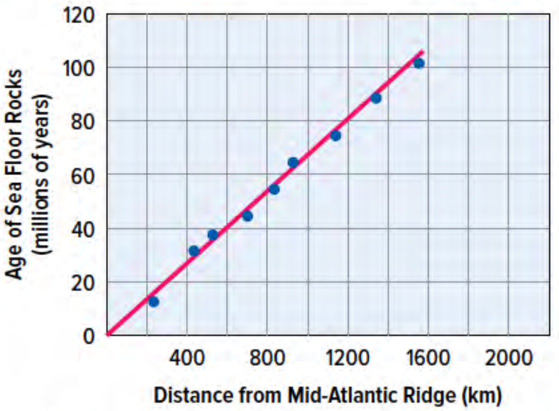
Connect to Investigation 4-C on page 287

Check Your Understanding of **Topic 4.1**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Describe the role that Pangaea played in Alfred Wegener's hypothesis. PA
2. Why did the ages of rocks at mid-ocean ridges puzzle scientists? PA
3. How do the theories of plate tectonics and continental drift differ? PA C
4. Use a diagram or graphic organizer to compare three key facts about Earth's layers. PA E C
5. The graph shows ages and locations of rock samples taken at the bottom of the mid-ocean ridge in the Atlantic Ocean. Each dot represents a sample of rock. PA E AI



   a) What is the age of the oldest rock and the youngest rock?
   b) How far would you have to travel east or west from the mid-ocean ridge before you found rocks that were 60 million years old?
   c) Describe the relationship between the age of rocks in the Atlantic Ocean and the distance they are from the mid-ocean ridge.
   d) What conclusion could you draw from this graph?

6. Why was there so little information about the oceans during the time that Wegener was collecting evidence for his theory? Why was it possible to learn much more about the oceans during and after the 1940s? E C

Connecting Ideas

7. Many scientists who contributed to the theory of plate tectonics were taught in school that the fixed-continent hypothesis was fact. Now the theory of plate tectonics is used to describe the movement of Earth's surface.
   a) Look up the meaning of the word "fact." How can facts change? What does this tell you about science and scientific discoveries?
   b) Think of a fact that you recently learned. What discovery may make you question whether it is a fact or not? E AI
8. Compose a letter to the editor of a newspaper from a scientist in the early 1900s arguing against the continental drift hypothesis. C PA

Making New Connections

9. If continents continue to move, is it possible that a new supercontinent will form? Which continents might be next to each other 200 million years from now? AI QP

INVESTIGATION 4-A

STRUCTURED INQUIRY

Wegener’s Evidence for Piecing Together Pangaea

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Applying and Innovating

What You Need

- photocopy of continents
- scissors
- coloured pencils
- 21.5 cm × 28 cm sheet of paper
- glue

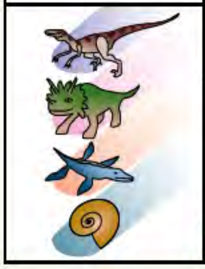
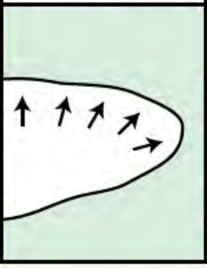
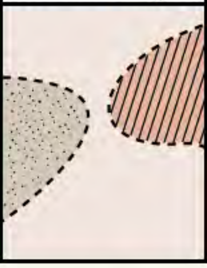
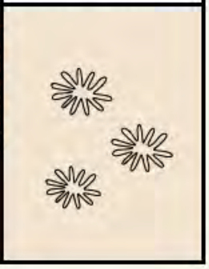
Alfred Wegener (1880–1930) was one of many people who noticed that the shapes of some continents looked like they were once joined together. Wegener collected evidence and analyzed data in hopes of showing that this was more than just chance. In this investigation, you will use some of the evidence Wegener collected to assemble a paper model of the supercontinent Pangaea that he hypothesized.

Question

How does geological and biological evidence support the existence of Pangaea?

Procedure

1. Obtain a sheet of paper with the outlines of the continents. Cut out each continent, with its continental shelf. The dotted lines represent the edges of the continental shelves.
2. The key below represents different types of evidence that Wegener collected. The symbols in the key are drawn on the continent shapes you cut out.

Fossils	Glacial Deposits	Matching Mountain Ranges	Coal Deposits
			

3. Piece together the continents using the shapes of continents and the evidence as a guide.
4. Some of Wegener’s evidence is summarized in the table on the opposite page. Check your assembled supercontinent against the evidence described in the table. Modify your representation if needed.

5. Have your teacher check your assembled Pangaea. Then, glue the pieces onto the larger piece of paper.

Process and Analyze

1. Summarize the process you used to assemble the supercontinent.
2. Why did the pieces you fit together include the continental shelf?
3. Why was using several pieces of evidence, instead of just one, important?

Evaluate, Apply, and Communicate

4. Was the supercontinent you assembled just like the Pangaea supercontinent that Wegener proposed? If not, explain how it is different and why.
5. To discredit Wegener's ideas, some scientists suggested that land bridges once existed between continents. For example, they argued that a land bridge between South America and Africa would have allowed animals to pass between these continents, and that is why fossils of these animals are found on both continents. It was suggested that these land bridges later sank into the ocean. Do you think this is a possible scenario? Explain your answer.

Wegener's Evidence (for Procedure Step 4)	On Your Map?
Grooves in rock once formed by large, moving glaciers are found in southern Africa, South America, Australia, and India. When these places are fitted together, the grooves expand outward in all directions. This supports the idea that an ice cap was once centred over Antarctica and South Africa and the ice moved outwards from there.	
When the continents are pieced together, there is a continuous band of fossils of the reptile *Mesosaurus* through southern Africa and the eastern coast of South America.	
When the continents are pieced together, there is a continuous band of fossils of the plant *Glossopteris* through Africa, South America, Australia, Antarctica, Madagascar, and India.	
When the continents are pieced together, there is a continuous band of fossils of *Lystrosaurus* through east Africa, India, and Antarctica.	
When the continents are pieced together, there is a continuous mountain range on the east coast of North America, North Africa, and Europe.	
Coal deposits have been found in Antarctica. The coal is thought to form from plants that grew in warm weather. Therefore, Antarctica was likely in a much warmer climate than it is now.	

INVESTIGATION

4-B

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

What You Need

Possible materials include:

- large sheets of paper
- coloured pencils or markers
- craft materials, such as foam blocks, glue, and coloured clay

Modelling Sea Floor Spreading

Sea floor spreading is a process that describes how new oceanic crust forms at mid-ocean ridges. In this investigation, you will work with your classmates to develop a model that shows how sea floor spreading occurs.

Question

How can a model show sea floor spreading?

Procedure

1. Decide how you will use a model to represent sea floor spreading. Your goal is to design and build the model to show what happens during sea floor spreading.
2. Use the following questions to guide your decisions.
   - What important features and processes do you need to show? Remember that your model must be consistent with the evidence collected at mid-ocean ridges.
   - What materials do you need to safely build the model? Are these available from your teacher?
   - What is the procedure to make the model?
3. Have your teacher approve your idea for your model.
4. Build your model and demonstrate it to the class.

Analyze and Interpret

1. Draw a design of your model. Make a list of the features that are represented. Were you able to represent all the features? Why or why not?
2. Describe which feature was most difficult to represent.

Conclude and Communicate

3. Assess how well your model worked. How could you improve it?
4. As a class, compare your models. Make a list of the strengths and weaknesses of the models.

INVESTIGATION

4-C

OPEN INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

What You Need

- map of tectonic plates

Using Maps

Maps are common ways of representing information about locations of features and processes on Earth. In this investigation, you will use maps to answer a question you have about tectonic plates, earthquakes, and volcanic activity.

Procedure

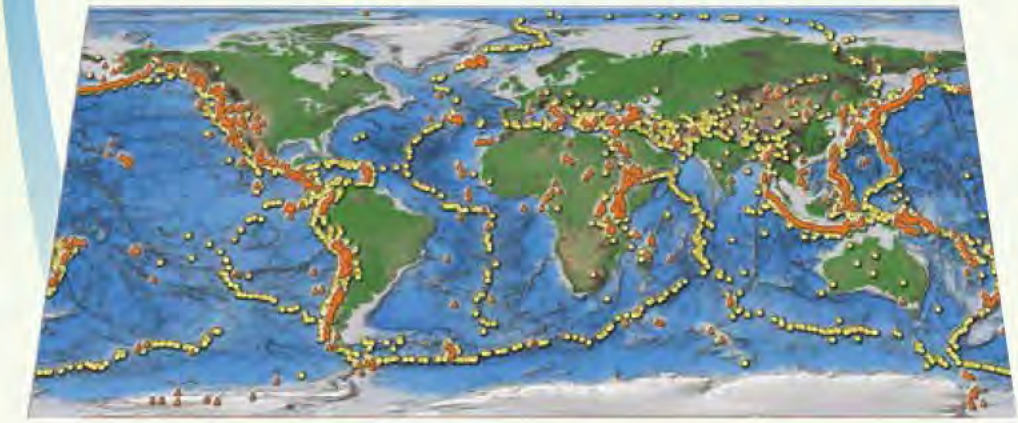
1. Write out any questions you have about the relationship between tectonic plate boundaries and locations of earthquakes and volcanoes.
2. Decide which question you will investigate using the information in the maps, and determine how you will use the maps. Carry out your plan.

Process and Analyze

1. Did you determine the answer to your question? If so, what is it? If not, why were you not able to? What other information would you need to answer your question?

Evaluate and Communicate

2. Create an infographic for people who live in areas where earthquakes and volcanoes are common. Include a description of the theory of plate tectonics and how it explains why those areas experience these geologic activities. It will be for people of different ages and backgrounds, who live in different countries. How can you develop the notice for the largest audience?



Yellow circles show where earthquakes happened. Orange triangles show volcanic eruptions.

TOPIC
4.2

What are tectonic plates and how is their movement linked to geological processes?

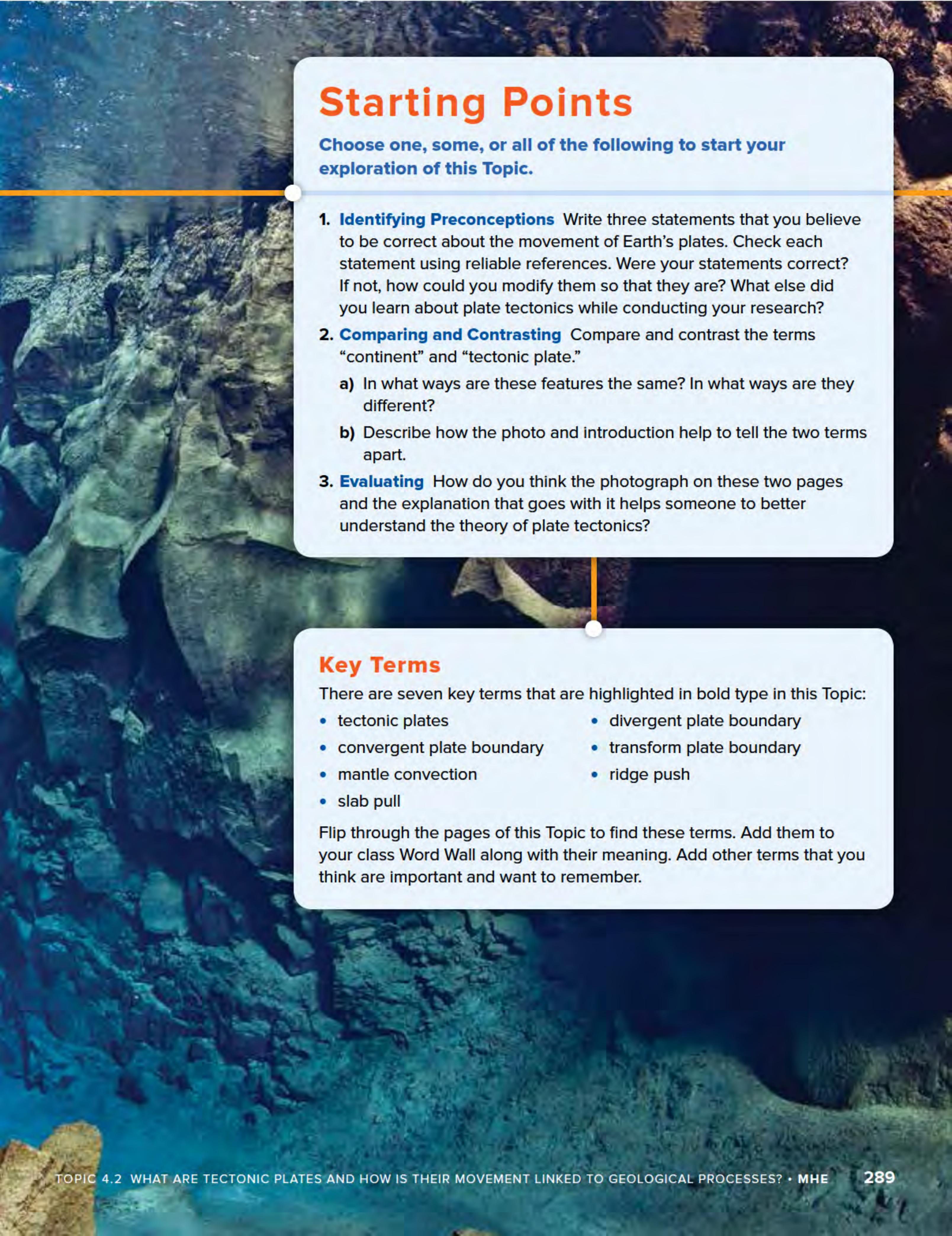
Key Concepts

- Earth's surface is made of huge rocky plates.
- Tectonic plates move relative to each other, causing certain geologic activities.
- Mantle convection contributes to tectonic plate movement.

Curricular Competencies

- Collaboratively plan an investigation to answer a question.
- Demonstrate an understanding and appreciation of evidence.
- Seek patterns and connections in data from secondary sources
- Transfer and apply learning to new situations.

If you want to visit western Europe, the quickest way is to fly by plane from Canada's east coast. But what if you were in a contest to get from North America to Europe in the least amount of time? The diver in the photo isn't in a contest, but the trip from one continent to the other takes the diver only a few seconds! This feat isn't quite so astonishing when you know something about where this photo was taken. The Thingvellir region of Iceland is an area of sea floor spreading. In this place, the North American plate and the Eurasian plate are slowly moving apart. The rocky features on each side of the diver are those tectonic plates.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Write three statements that you believe to be correct about the movement of Earth's plates. Check each statement using reliable references. Were your statements correct? If not, how could you modify them so that they are? What else did you learn about plate tectonics while conducting your research?
2. **Comparing and Contrasting** Compare and contrast the terms "continent" and "tectonic plate."
   - **a)** In what ways are these features the same? In what ways are they different?
   - **b)** Describe how the photo and introduction help to tell the two terms apart.
3. **Evaluating** How do you think the photograph on these two pages and the explanation that goes with it helps someone to better understand the theory of plate tectonics?

Key Terms

There are seven key terms that are highlighted in bold type in this Topic:

- tectonic plates
- convergent plate boundary
- mantle convection
- slab pull
- divergent plate boundary
- transform plate boundary
- ridge push

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Earth's surface is made of huge rocky plates.

Activity

Structural Zones of Earth's Interior

Have you heard of the lithosphere and asthenosphere? What do you think they are? Explain your answer.

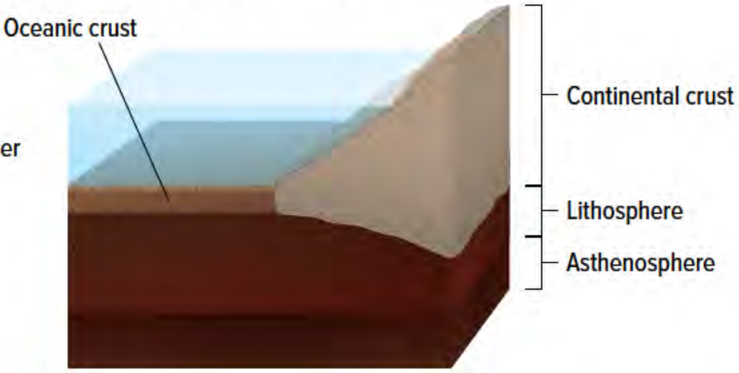
As shown in Figure 4.9, Earth's *lithosphere* is the outer layer of solid rock that is composed of crust and part of the upper mantle. According to the theory of plate tectonics, the lithosphere consists of very large slabs of rocky material, called **tectonic plates**. Some tectonic plates, such as the Pacific plate and the Juan de Fuca plate, are made up of only oceanic crust. Most tectonic plates, such as the North American plate, are made up of both oceanic crust and continental crust.

Tectonic plates move slowly and float on a layer called the *asthenosphere*. Material that makes up the asthenosphere is so hot that it behaves like a plastic material, making this layer much less rigid than the lithosphere. The asthenosphere flows like toothpaste or melted tar. This enables Earth's plates to move because the hotter, plastic mantle material beneath them can flow. The interactions between lithosphere and asthenosphere help to explain plate tectonics.

tectonic plates parts of the crust and uppermost mantle that move over Earth's surface

Figure 4.9 Earth's lithosphere consists of tectonic plates. **What is the key role of the asthenosphere in the theory of plate tectonics?**

Oceanic crust is made mostly of basalt. It is denser than continental crust. Oceanic crust can be between 5 km and 8 km thick.



Continental crust is made mostly of granite. It is less dense than oceanic crust. Continental crust can be between 10 km and 70 km thick.

Before you leave this page . . .

1. Tectonic plates are composed of which parts of Earth's layers?
2. What are two types of tectonic plates? Describe two features of each.

CONCEPT 2

Tectonic plates move relative to each other, causing certain geologic activities.

Activity

Modelling Plate Movements

Use your hands and the information in Table 4.1 to model three ways plates can move. Place your hands side-by-side, touching and palms down, parallel to the floor. Move your hands apart to simulate plate movement along a mid-ocean ridge. Now place your hands parallel to the floor with palms down and fingertips touching. Force one hand down under the other to show what can happen when two plates move toward each other. Finally, place your hands, palms down, parallel to the floor with your index fingers touching and parallel to each other. Slide your hands back and forth against each other to simulate plate motion along a transform plate boundary.

Tectonic plates move in different directions and at different rates relative to one another. Plates interact with each other at their edges, or *plate boundaries*. Because we compare the motion of one plate with the plates around it, we refer to the "relative motion" of two plates at a plate boundary. When two plates separate and create new oceanic crust, a **divergent plate boundary** forms. When two tectonic plates collide, they form a **convergent plate boundary**. A **transform plate boundary** forms when two plates slide horizontally past each other. These three types of plate boundaries are shown in Table 4.1 on the next page, with examples of geological features associated with each type.

divergent plate boundary where two tectonic plates move apart

convergent plate boundary where two tectonic plates collide

transform plate boundary where two tectonic plates slide past each other horizontally

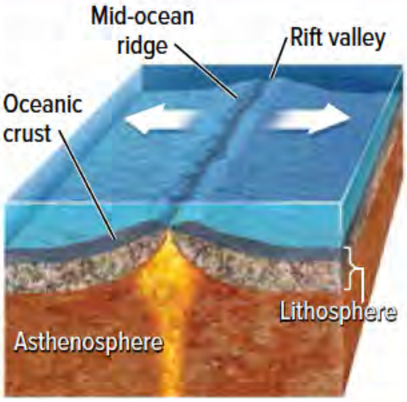
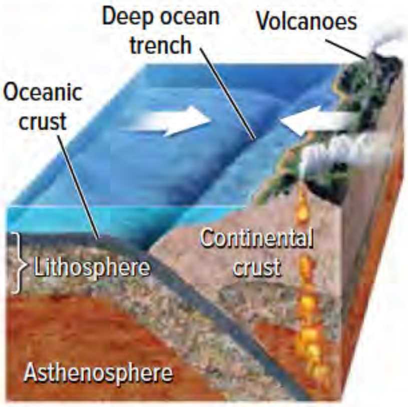
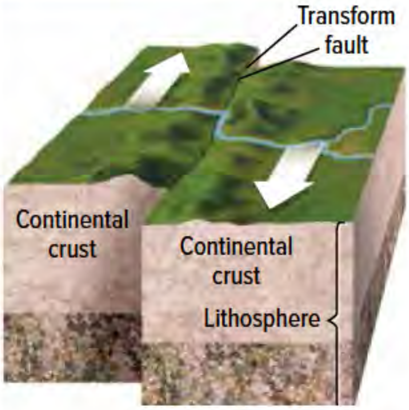
Extending the Connections

Plate Boundaries Around British Columbia

Draw a map to identify the relative positions and movement of the tectonic plates and their boundaries that lie near B.C. Identify all transform, convergent, and divergent plate boundaries, as well as the Juan de Fuca Ridge. What is a geologic fault? What faults lay along the west coast of Canada? What are the Mendocino Triple Junction and Cascadia Subduction Zone? Add these to your map.

Connect to Investigation 4-D on pages 296–297

Table 4.1 **Interactions of Earth's Tectonic Plates**

Plate Boundary	Relative Motion	Example
Divergent Plate Boundary When two plates separate and create new oceanic crust, a divergent plate boundary forms. This process occurs where the sea floor spreads along a mid-ocean ridge, as shown to the right. This process can also occur in the middle of continents and is referred to as a continental rifting.	 Mid-ocean ridge Rift valley Oceanic crust Lithosphere Asthenosphere	 The Endeavour hydrothermal vents, created as the Juan de Fuca plate moves away from the Pacific plate.
Convergent Plate Boundary When two tectonic plates collide, they form a convergent plate boundary. When they collide, the denser crust eventually goes below the less-dense crust. This process is called *subduction*. Subduction causes deep sea trenches to form. Volcanoes and mountains, such as Mount Garibaldi and Mount Meager, form at these boundaries and earthquakes are common.	 Deep ocean trench Volcanoes Oceanic crust Continental crust Lithosphere Asthenosphere	 Mount Garibaldi was created as a result of the Juan de Fuca plate subducting under the North American plate.
Transform Plate Boundary This boundary was first identified by a Canadian geologist named John Tuzo Wilson. A transform plate boundary forms when two plates slide horizontally past each other. The Queen Charlotte Fault results from movement along a transform plate boundary. Earthquakes are very common at these boundaries.	 Transform fault Continental crust Continental crust Lithosphere	Earthquake ALASKA BRITISH COLUMBIA Haida Gwaii Region In October 2012, an earthquake with a magnitude of 7.7 originated from movement along the Queen Charlotte Fault.

Before you leave this page . . .

1. What is subduction? When and why does it occur?
2. Describe the geological processes that occur at a divergent boundary. Relate it to what you learned about sea floor spreading.

CONCEPT 3

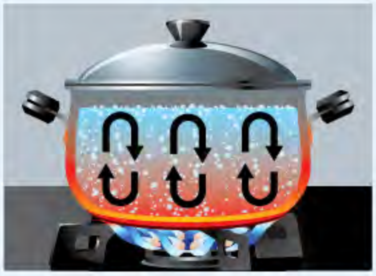
Mantle convection contributes to tectonic plate movement.

Activity

Modelling Heat Transfer

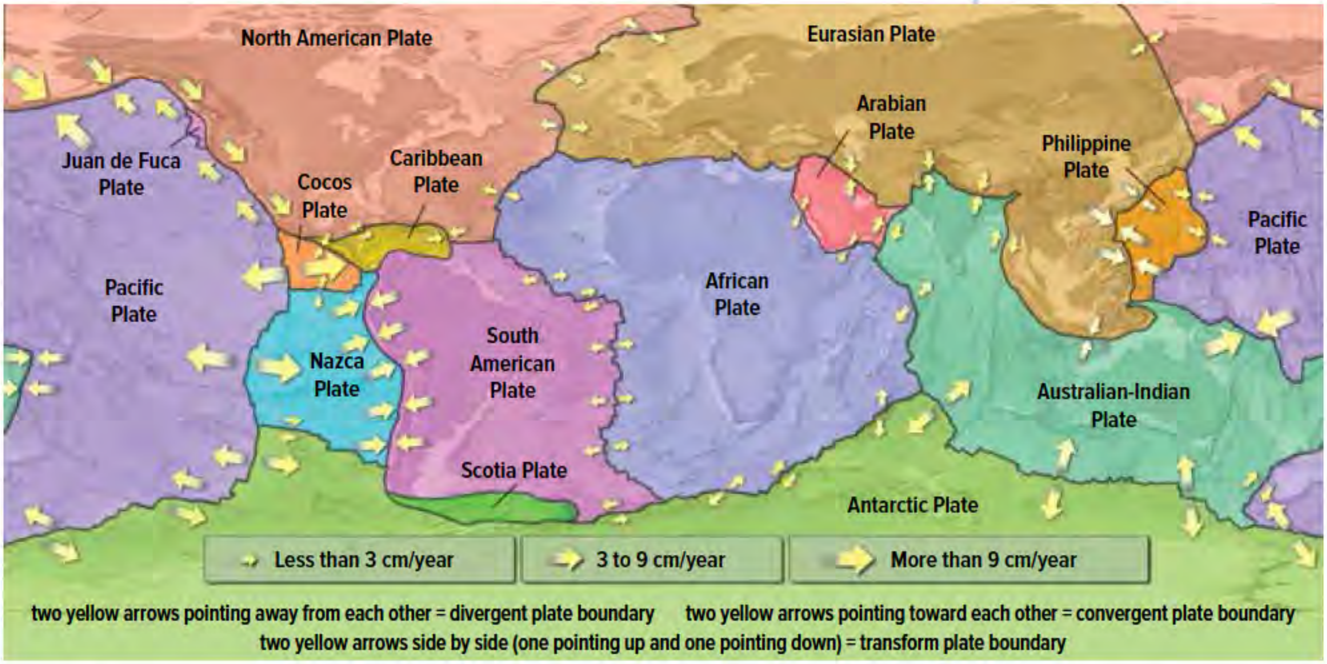
Convection is a process in which a warm fluid (liquid or gas) moves from one place to another, carrying heat with it. The fluid moves because of differences in density. The arrows show the direction of fluid movement.

- Where is the warmer and cooler water?
- Why does cooler water sink and warmer water rise?
- How could a process like this occur in the mantle, and how could it affect tectonic plates?



The movement of tectonic plates is measured using satellites, lasers, and other technologies. For example, the Global Positioning System (GPS) uses small radio receivers to record signals from several satellites that orbit Earth. These GPS receivers are placed at sites on land. By placing receivers on different tectonic plates, scientists can measure how fast the plates are moving and monitor the positions of the plates over time. Plates move at a rate of 1 to 15 cm per year. The map in Figure 4.10 shows the relative movements of the plates along the major plate boundaries.

Figure 4.10 Arrows show whether the plate boundary is divergent, convergent, or transform. Wider arrows show faster movement than narrower arrows.


North American Plate
Eurasian Plate
Arabian Plate
Juan de Fuca Plate
Cocos Plate
Caribbean Plate
Philippine Plate
Pacific Plate
Pacific Plate
African Plate
South American Plate
Nazca Plate
Australian-Indian Plate
Scotia Plate
Antarctic Plate
Less than 3 cm/year
3 to 9 cm/year
More than 9 cm/year
two yellow arrows pointing away from each other = divergent plate boundary
two yellow arrows pointing toward each other = convergent plate boundary
two yellow arrows side by side (one pointing up and one pointing down) = transform plate boundary

Mantle Convection

Recall that Earth's mantle is made of partially melted material. Energy from radioactive decay of some elements in Earth's interior and from Earth's core heats up parts of the mantle. Warmer, less dense material rises and cooler, denser material sinks. This causes very large *convection currents* within the mantle. As the mantle material moves, it drags the tectonic plates above with it. Figure 4.11 shows how **mantle convection** is thought to occur.

mantle convection current in the mantle where cooler, denser material sinks and warmer, less dense material rises

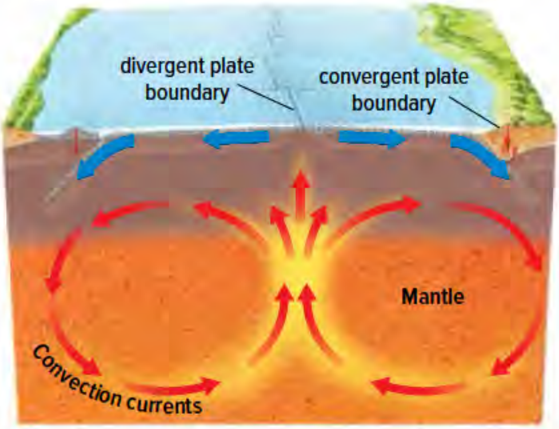
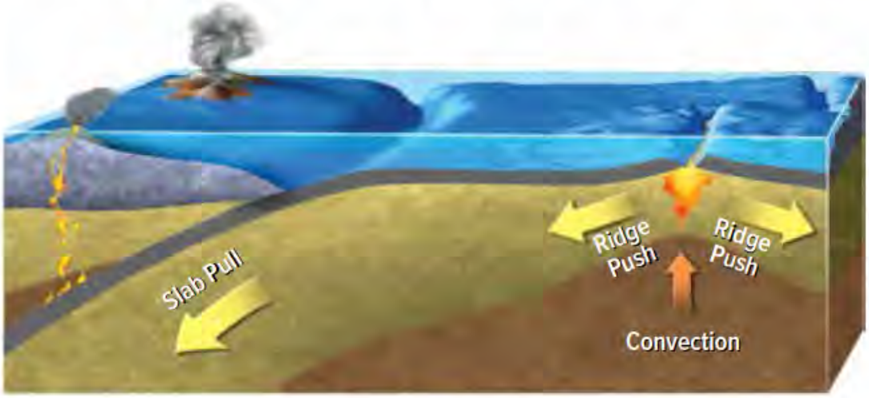


Figure 4.11 Convection currents are thought to drive tectonic plate motion. **Analyzing** Describe how mantle convection helps transfer heat between Earth's interior and exterior.

Scientists think there are several processes that determine how mantle convection affects the movement of tectonic plates. Two important processes are **ridge push** and **slab pull** (Figure 4.12).

ridge push new material pushes older material aside, causing tectonic plates to move apart

slab pull pulling of a tectonic plate due to gravity and subduction



Slab Pull
As the leading edge of a subducting plate sinks, it pulls the rest of the plate with it at convergent plate boundaries. Gravity and convection assist this movement.

Ridge Push
Rising material spreads out as it reaches the upper mantle. This causes the lithosphere to lift and push tectonic plates apart at divergent plate boundaries.

Figure 4.12 Ridge push and slab pull are thought to move tectonic plates. **Identify a convergent plate boundary and a divergent plate boundary in the illustration.**

Before you leave this page . . .

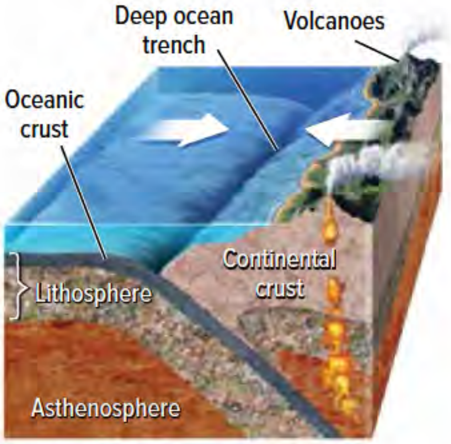
1. Describe mantle convection.
2. Describe how slab pull and ridge push each contribute to plate movement.

Check Your Understanding of **Topic 4.2**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Use your current understanding of the theory of plate tectonics to explain the shapes and positions of the continents. PA E
2. What is the relationship between the following two terms: "divergent boundary" and "sea floor spreading"? PA
3. Use the following diagram to answer the questions below. C PA



   a) What is represented in the diagram? Explain how you know.
   b) Write a caption for the diagram.
   c) Describe how the deep ocean trench and the volcanoes are forming.
4. Draw a sketch that represents a transform boundary. Make sure to label the boundary and the components of your diagram. Explain why Earth's crust is neither destroyed nor created at such a boundary. PA C
5. Some people say that the theory of plate tectonics is the modern version of the continental drift hypothesis. Do you agree or disagree with this statement? Provide at least two reasons that support your opinion. C E

Connecting Ideas

6. When scientists cannot study an event directly, they often use a model to represent it.
   a) Describe two advantages of using a model.
   b) Describe two disadvantages of using a model.
   c) Describe one topic in earth science where using a model is useful. Explain why you think a model is useful in that situation. PA AI
7. Draw a diagram comparing convection in a pot of water with convection in Earth's mantle. Relate the process to how scientists think tectonic plates move. C

Making New Connections

8. Through the use of space probes, scientists have discovered that some moons, planets, and dwarf planets of our solar system have geologic processes similar to those of Earth. For example, Jupiter's moon Io has volcanoes, and there is evidence of tectonic activity on Pluto, which is nearly 6 billion km from the Sun. What questions do you have about these kinds of discoveries? List at least four questions. Then choose one and suggest your own ideas for possible answers. QP AI

INVESTIGATION

4-D

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Comparing Plate Boundaries with Geologic Features and Processes

According to the theory of plate tectonics, rocky plates move across Earth's surface and interact at plate boundaries. In this investigation, you will analyze maps to identify examples of geological processes at convergent, divergent, and transform plate boundaries. (These boundaries appear on the map below.)

Question

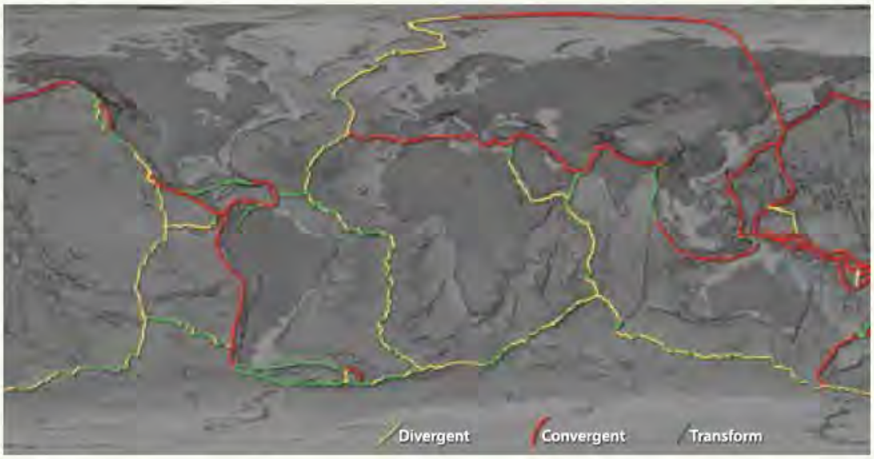
What geologic processes and features are associated with each type of plate boundary?

Procedure

1. Plan how you will use the maps to answer the question.
2. Decide how you will communicate the results of your analyses of the maps. For example, you may find a table format to be helpful. Then, carry out your plan.

Analyze and Interpret

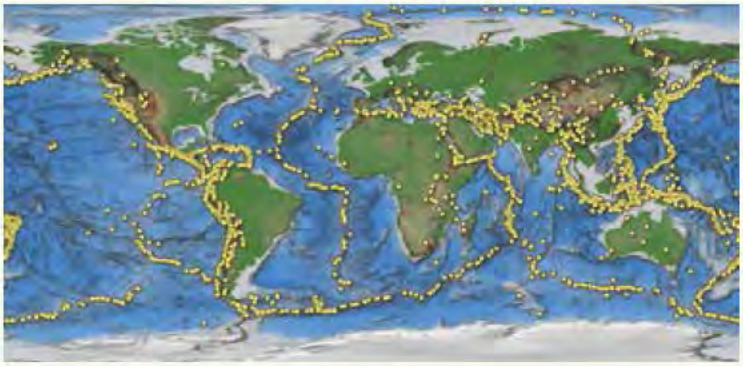
1. Draw a sketch of what happens at each type of plate boundary that results in geologic processes.
2. What geologic processes are not always associated with plate boundaries? What do you think causes these?



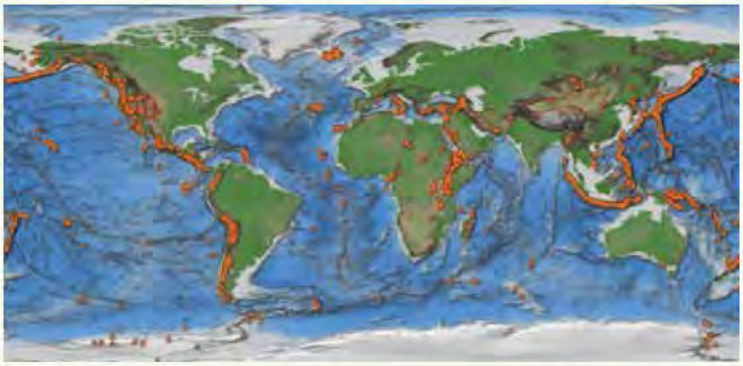
Conclude and Communicate

3. What geologic processes did you identify to be associated with each plate boundary?

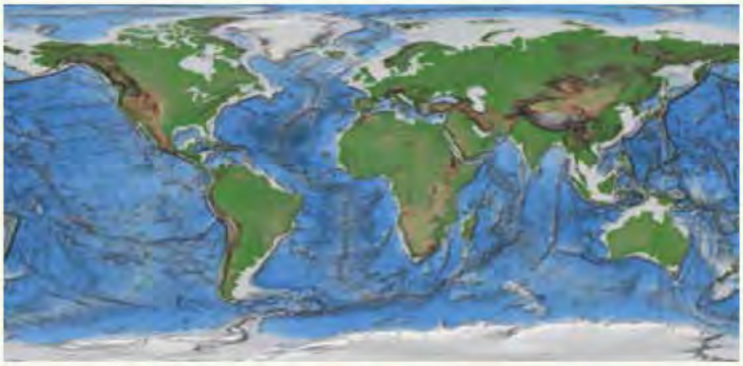
4. In what ways were the maps a useful way of representing the information? In what ways were they not useful?



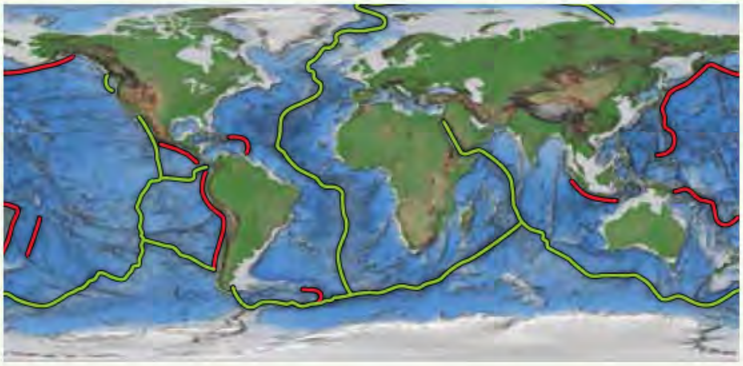
Yellow circles show where moderate to strong earthquakes have happened.



Orange triangles show the locations of active volcanoes.



High elevation is in brown, and low elevation is in green.



This map shows deep sea trenches (red) and mid-ocean ridges (green).

TOPIC 4.3

How does the theory of plate tectonics explain Earth's geological processes?

Key Concepts

- Most earthquakes occur near tectonic plate boundaries.
- Movement along faults produces seismic waves.
- Most volcanoes occur where oceanic crust collides with another plate.
- Mountain ranges can also form when continental crust collides.

Curricular Competencies

- Reflect on your investigation methods.
- Co-operatively design projects.
- Contribute to care for community.
- Express and reflect on a variety of experiences and perspectives of place.
- Transfer and apply learning to new situations.

Earth is changing all the time. Sometimes the changes can be immediately visible, such as when an earthquake or tsunami strikes. The photos on these pages show objects that washed up on the shoreline of British Columbia as a result of the earthquake and tsunami that occurred in Japan in 2011. Most of the time, Earth's surface is changing in slow, almost unnoticeable ways. The slow, steady movement of tectonic plates, the violent eruption of a volcano, the rumbling of the ground, and the gradual formation of mountain ranges are all caused by the movement of Earth's plates.

The theory of plate tectonics explains how earthquakes, volcanoes, and mountain ranges are linked together. It also allows scientists to explain how, where, and sometimes when these geologic processes occur.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Suppose your friend tells you that she is scared of earthquakes because they are all highly destructive and cause lots of damage. Would you agree with her statement? Why or why not? Share your response with your classmates. What do they think about the power of earthquakes? Are all earthquakes disastrous? How could you find out the answer?
2. **Testing Ideas** You have learned that the theory of plate tectonics relates many geologic processes.
    - **a)** How are earthquakes, volcanoes, and mountains related? Make a list of ideas that you have. Which ones could you test or investigate to see if they are valid? How would you test them?
    - **b)** Earthquakes, volcanoes, and mountains are very different, but all result from plate tectonics. How might the theory explain their differences? Make a list of your ideas.
3. **Investigating History** Many First Peoples have oral histories or mythologies about volcanoes. For example, Hawaiians believed that the Fire Goddess Pele lived inside a volcano. They believed the volcano erupted when she became angry. Find an oral history or myth about volcanoes. Tell it in your own words.

Key Terms

There are eight key terms that are highlighted in bold type in this Topic:

- earthquake
- epicentre
- fault
- seismographs
- focus
- magnitude
- seismic waves
- volcano

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Most earthquakes occur near tectonic plate boundaries.

Activity

Modelling a Geologic Fault

Use the information in Table 4.2 to build models of the three types of faults. In what ways does your model accurately represent a fault? What features are not represented by your model? Compare your model with models built by your classmates. Make a list of the advantages of the models and describe the challenges with using models to represent faults.

If you read or listen to the news, you know that earthquakes can happen all over the world. However, exactly where they occur is not random. Almost all earthquakes occur along plate boundaries. Figure 4.13 shows locations of major earthquakes that have happened worldwide in recent history. Notice the pattern of earthquake activity.

Tectonic plate boundaries are where there is greatest stress on the rock in Earth's crust. Movements in Earth's crust can squeeze, stretch, or twist the rock. This applies pressure to the rock. Imagine bending a stick with your hands. At some point, the stick will not bend anymore and it breaks. When the pressure on the rock is applied too quickly or is larger than the strength of the rock, the rock breaks and the stored energy in the rock is released in the form of an earthquake.

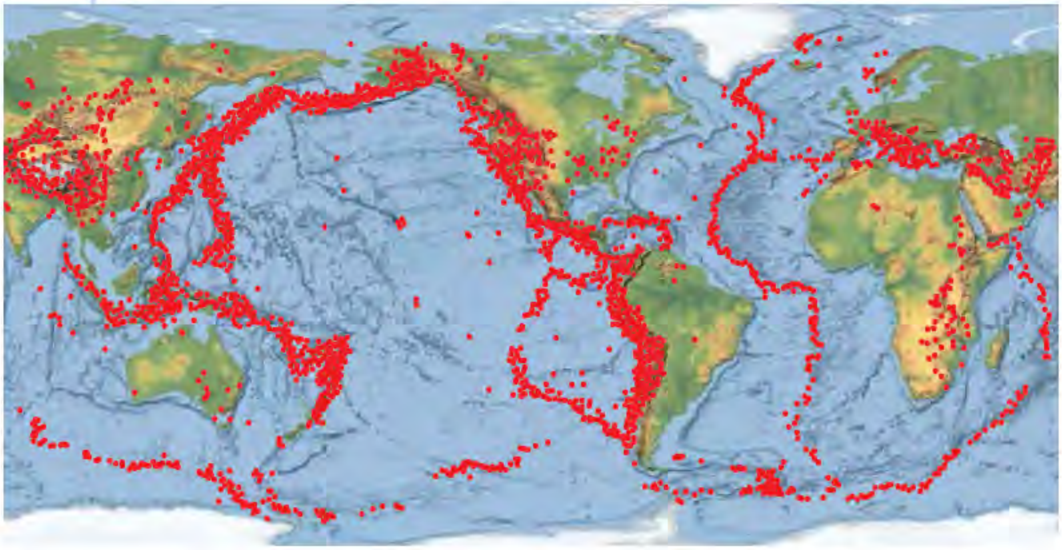


Figure 4.13 Almost 80% of all major earthquakes occur in the Circum-Pacific seismic belt.

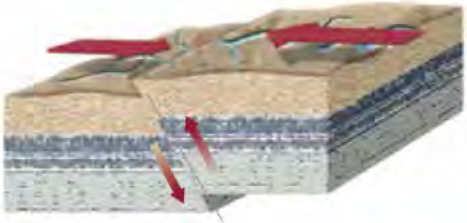
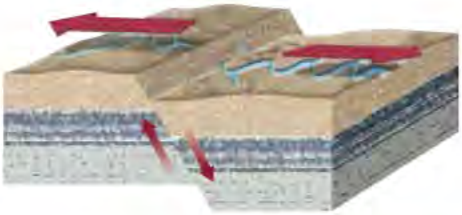
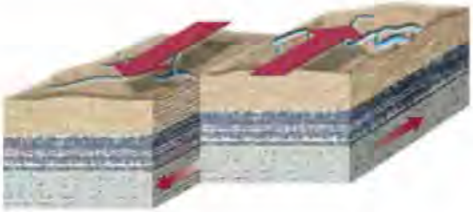
Earthquakes Happen at Faults

An **earthquake** is the natural movement or vibration of the ground that happens when part of Earth's crust shifts. Earthquakes usually occur when rocks suddenly shift along a break in the rock, releasing built-up pressure. The break where movement happens is called a **fault**. During an earthquake, one block of rock slides against or alongside another block of rock at a fault. Three types of faults can form: a reverse fault, a normal fault, and a strike-slip fault. Table 4.2 shows what happens at each type of fault. A *fault line* is the line along the surface of the ground where the break in the rock happens.

earthquake ground-shaking release of energy when a break in the crust occurs

fault large break in rock

Table 4.2 Types of Faults

Reverse	When rock is squeezed together and one block rides up to overlap the other block, a reverse fault forms. The crust is shortened, horizontally.	
Normal	When rock is pulled apart and one block slips downward, a normal fault forms. The crust is lengthened.	
Strike-slip	When blocks of rock move past each other horizontally, a strike-slip fault forms.	

Before you leave this page . . .

1. Describe the relationship between the locations of tectonic plates and the locations of major earthquakes.
2. What happens at a fault?
3. You find out that a friend's parents are considering buying a house near a fault line. Make a list of three questions they should find answers to before buying the house.

CONCEPT 2

Movement along faults produces seismic waves.

Activity

Seismic Slinky™ Waves

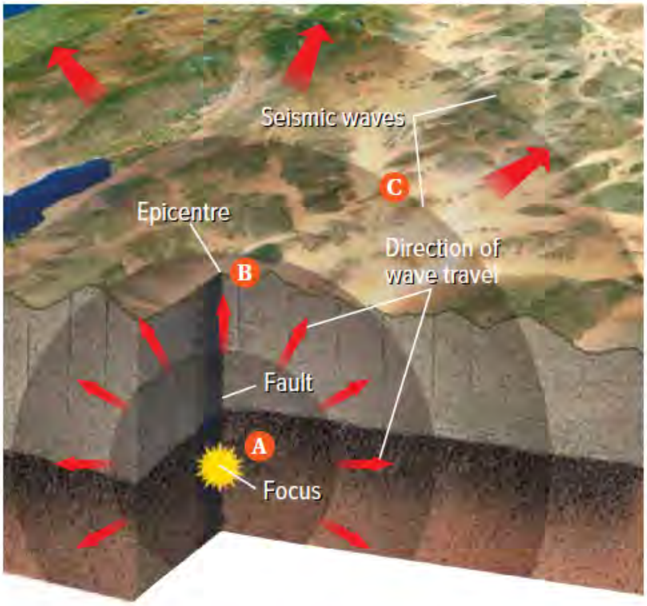
Working with a partner, use the information in Table 4.3 to model the three types of seismic waves using a Slinky™. What did you need to do with the Slinky to generate P waves? S waves? L waves? Describe the movement of each type of wave that you generated using the Slinky™.

focus location in Earth where an earthquake starts

seismic waves vibrations caused by release of energy during an earthquake

epicentre point on Earth's surface above where an earthquake starts

Study Figure 4.14. It shows what happens in Earth's interior when an earthquake occurs. An earthquake starts at a location called the **focus**. The focus is the point where breakage of rock first happens. The focus is usually at least several kilometres below the surface of Earth. As an earthquake occurs, rocks along a fault move into a new position and the ground feels like it is vibrating. The vibrations are **seismic waves**. An earthquake's **epicentre** is the point on the surface of Earth that is directly above the focus. When people describe where an earthquake has occurred, they usually refer to the epicentre of the earthquake.



Ⓐ The focus is the point where breakage of rock inside Earth first happens.

Ⓑ As an earthquake occurs, seismic waves leave the focus in all directions.

Ⓒ An earthquake's epicentre is the point on the surface of Earth that is directly above the focus.

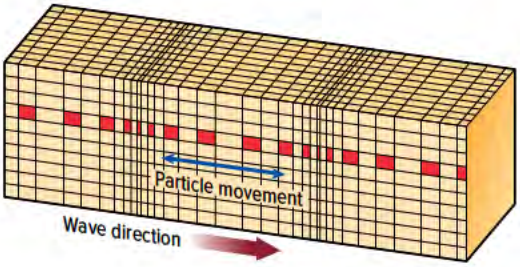
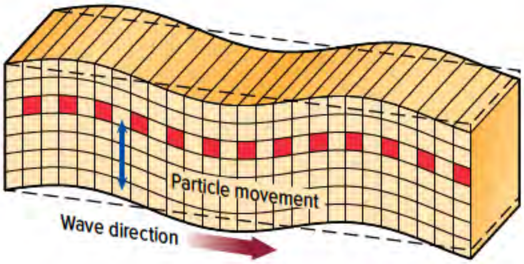
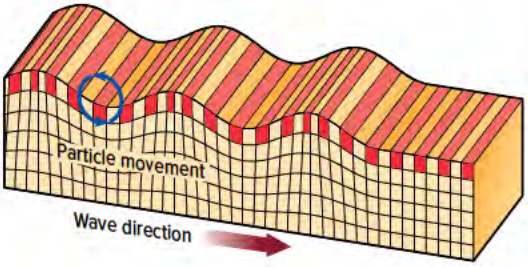
Figure 4.14 When an earthquake happens, seismic waves travel out from the focus.

Types of Seismic Waves

Table 4.3, on the next page, describes the three types of waves and the rock movements they cause when an earthquake happens.

Connect to Investigation 4-E on pages 314–315

Table 4.3 **Types of Seismic Waves**

Wave Type	Characteristics	Effect on Rock Particles	Where They Travel
Primary Waves (P waves)	• move the fastest • are the first ones detected in an earthquake	• cause rock particles to move forward and backward 	• can travel through both solids and liquids
Secondary Waves (S waves)	• move slower than P waves	• cause rock particles to move up and down 	• can only travel through solids
Surface Waves (L waves)	• are the slowest of the three waves • are on the surface and often cause the greatest damage	• cause rock particles to move both up and down and side to side 	• can travel along the surface of Earth and not through Earth's interior

Extending the Connections

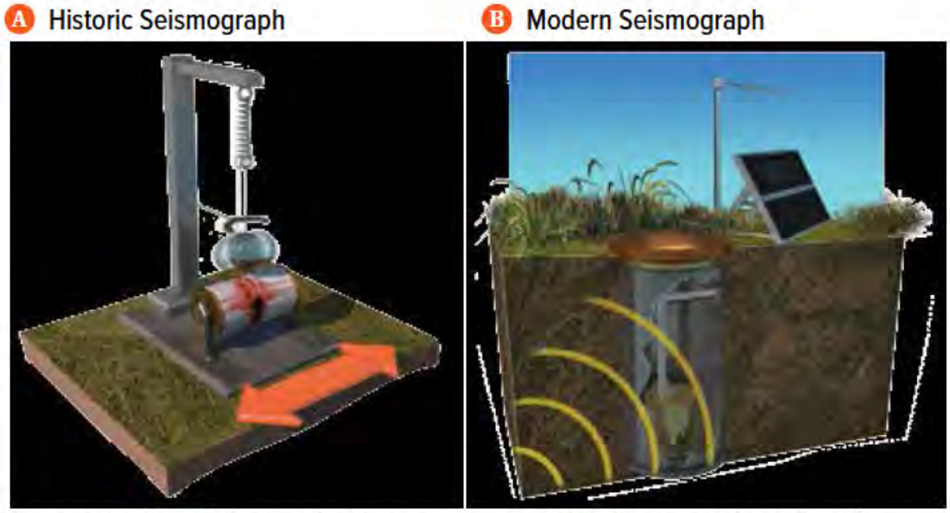
Seismic Waves Provide Information About Earth's Interior

Scientists have identified and divided Earth's interior into layers based on the composition and properties of the materials in each layer. Recall that these layers are the crust, mantle, inner core, and outer core. Find out how scientists use S and P seismic waves from earthquakes to learn about Earth's interior.

How Earthquakes Are Measured

seismograph instrument that measures and records ground vibration

Seismic waves are detected and recorded by scientific instruments called **seismographs**. A seismograph includes a seismometer, which detects ground motion, and a device that amplifies and records the signal. Study Figure 4.15 to find out how a seismograph works. When an earthquake occurs, seismic data from many instruments at different stations are uploaded to computers that process the information and determine the strength and location of the earthquake.



This device only records ground movement parallel to the red arrows. So, it only records a single direction.

This device records north-south, east-west, and up-down motion using three seismometers.

Figure 4.15 A Early models of seismographs used a seismometer made of a suspended mass in a frame. B Modern seismographs contain three electronic seismometers to record three components of motion. What non-earthquake events could interfere with seismograph recordings?

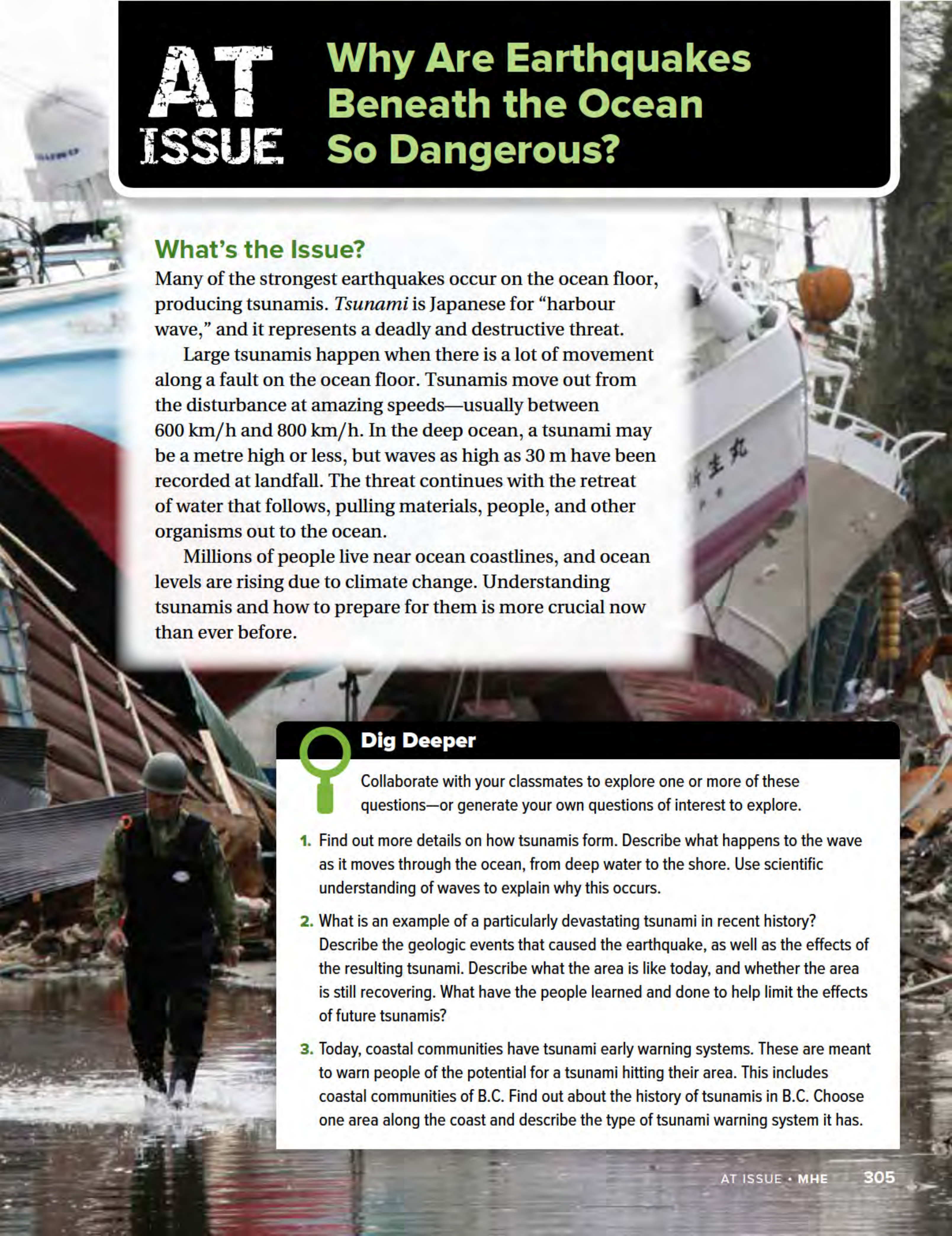
magnitude for earthquakes, a number that represents strength

The **magnitude** of an earthquake refers to how strong the earthquake is. News reports of earthquakes usually refer to the magnitude of an earthquake using the Richter scale. The *Richter scale* is based on the size of the largest seismic waves that are formed. The higher the number, the greater the strength of the earthquake. Each number on the scale represents a 10-fold difference. For example, a magnitude-8 earthquake is 10 times larger than a magnitude-7 earthquake and a hundred times larger than a magnitude-6 earthquake. In general, earthquakes that are magnitude-4 or less do not cause damage. The world's strongest recorded earthquake was a magnitude-9.5, in Chile in 1960.

Connect to Investigation 4-F on page 316

Before you leave this page . . .

1. Where is the epicentre of an earthquake?
2. Why do you think seismographs are buried and placed far from highly populated areas?



AT ISSUE Why Are Earthquakes Beneath the Ocean So Dangerous?

What's the Issue?

Many of the strongest earthquakes occur on the ocean floor, producing tsunamis. *Tsunami* is Japanese for "harbour wave," and it represents a deadly and destructive threat.

Large tsunamis happen when there is a lot of movement along a fault on the ocean floor. Tsunamis move out from the disturbance at amazing speeds—usually between 600 km/h and 800 km/h. In the deep ocean, a tsunami may be a metre high or less, but waves as high as 30 m have been recorded at landfall. The threat continues with the retreat of water that follows, pulling materials, people, and other organisms out to the ocean.

Millions of people live near ocean coastlines, and ocean levels are rising due to climate change. Understanding tsunamis and how to prepare for them is more crucial now than ever before.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. Find out more details on how tsunamis form. Describe what happens to the wave as it moves through the ocean, from deep water to the shore. Use scientific understanding of waves to explain why this occurs.
2. What is an example of a particularly devastating tsunami in recent history? Describe the geologic events that caused the earthquake, as well as the effects of the resulting tsunami. Describe what the area is like today, and whether the area is still recovering. What have the people learned and done to help limit the effects of future tsunamis?
3. Today, coastal communities have tsunami early warning systems. These are meant to warn people of the potential for a tsunami hitting their area. This includes coastal communities of B.C. Find out about the history of tsunamis in B.C. Choose one area along the coast and describe the type of tsunami warning system it has.

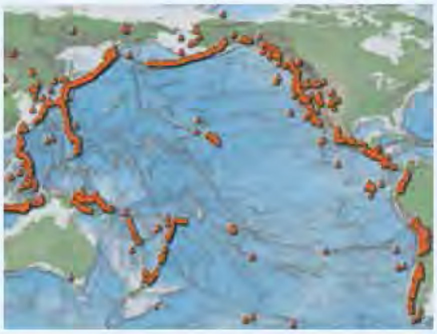
CONCEPT 3

Most volcanoes occur where oceanic crust collides with another plate.

Activity

British Columbia and the Pacific Ring of Fire

The majority of Earth's earthquakes and volcanoes occur in an area called the Ring of Fire. There is constant earthquake and volcanic activity in this area—and British Columbia is a part of it. Find out the following. Describe how plate tectonic activity has resulted in the Ring of Fire. Which countries are often affected by plate movement in this area? Give two or three examples of populations that have been badly affected by the geologic activity in this region. Now answer any of your own questions about this area of the world.



volcano opening in Earth's surface where magma and other materials are released

Anywhere that magma from the mantle reaches Earth's surface can be called a **volcano**. Magma that has been released onto Earth's surface is called *lava*. Volcanic eruptions, such as the one shown in Figure 4.16, can send hot gases and volcanic ash flying high into the air. An eruption can also cause dangerous landslides that produce massive paths of destruction.

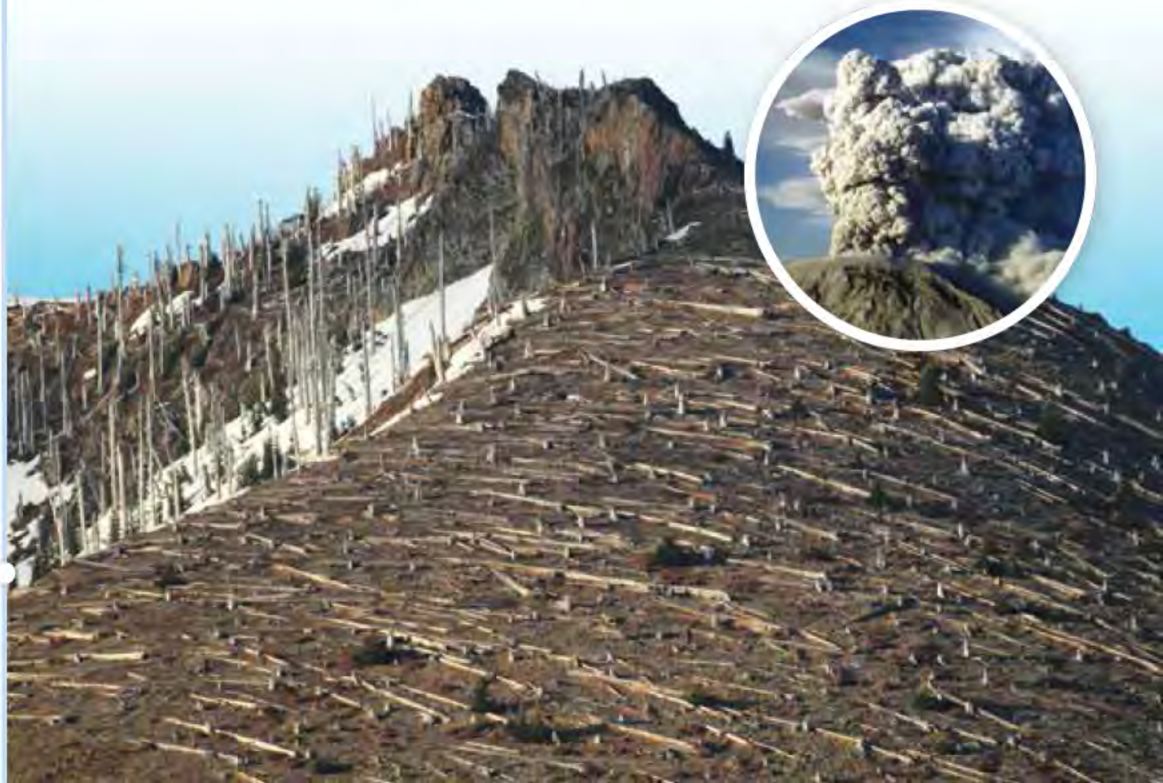
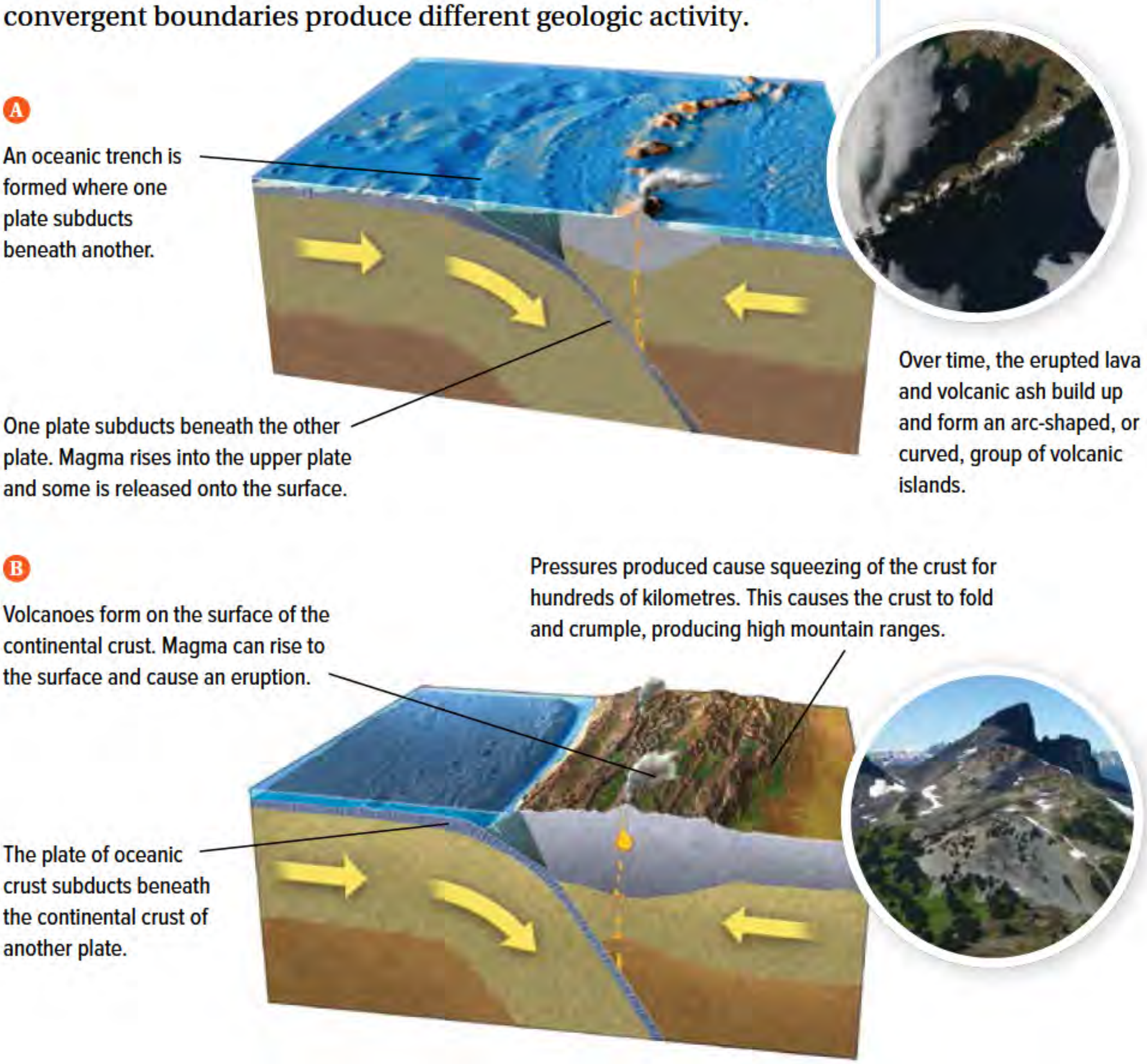


Figure 4.16 Mount St. Helens in Washington State erupted in 1980. This was the last major eruption near British Columbia.

Connect to Investigation 4-G on page 317

How Volcanoes Form at Plate Boundaries

Many volcanoes occur at convergent boundaries. Figure 4.17 shows two ways scientists think volcanoes can form. Part A shows what happens when crust from an oceanic plate collides with crust from another oceanic plate. This is often called an oceanic-oceanic convergent boundary. Part B shows what happens when oceanic crust collides with continental crust, at an oceanic-continental convergent boundary. Notice how these two types of convergent boundaries produce different geologic activity.



An oceanic trench is formed where one plate subducts beneath another.

One plate subducts beneath the other plate. Magma rises into the upper plate and some is released onto the surface.

Over time, the erupted lava and volcanic ash build up and form an arc-shaped, or curved, group of volcanic islands.

Volcanoes form on the surface of the continental crust. Magma can rise to the surface and cause an eruption.

Pressures produced cause squeezing of the crust for hundreds of kilometres. This causes the crust to fold and crumple, producing high mountain ranges.

The plate of oceanic crust subducts beneath the continental crust of another plate.

Figure 4.17 Ⓐ Oceanic-oceanic convergent plate boundaries form a pattern of islands called volcanic island arcs. The Aleutian Islands of Alaska are an island arc of volcanoes. Evidence indicates they have formed from the collision between the Pacific plate and the North American plate. Ⓑ Oceanic-continental convergent plate boundaries form large continental volcanoes. The Coast Mountain Range includes a series of dormant volcanoes. It is thought that they formed from the collision between the Juan de Fuca plate and the North American plate.

Hot Spot Volcanoes

In the early 1960s, many scientists did not support the theory of plate tectonics because it could not explain volcanic activity that was not near plate boundaries. In 1963, Canadian scientist John Tuzo Wilson proposed an idea to explain this. He suggested that tectonic plates could move over fixed areas called hot spots. *Hot spots* are defined as unusually hot regions of Earth's mantle where magma rises to the surface by breaking through weak parts of the lithosphere. **Figure 4.18** shows how the Hawaiian Islands are thought to have formed from a hot spot under the ocean.

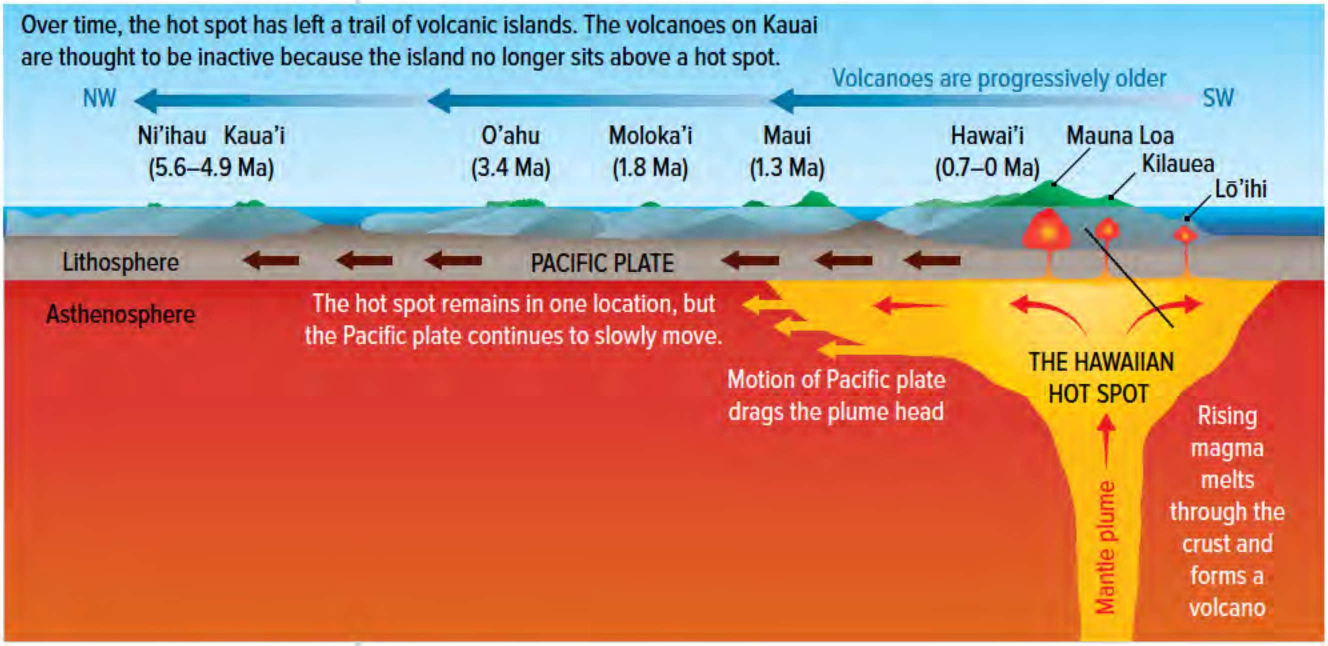


Figure 4.18 The volcanic islands of Hawaii are thought to have formed from a hot spot. **Analyzing** Which island has volcanic activity? How do you know?

Over time, the hot spot has left a trail of volcanic islands. The volcanoes on Kauai are thought to be inactive because the island no longer sits above a hot spot.
Volcanoes are progressively older
NW
SW
Ni'ihau
Kaua'i
(5.6–4.9 Ma)
O'ahu
(3.4 Ma)
Moloka'i
(1.8 Ma)
Maui
(1.3 Ma)
Hawai'i
(0.7–0 Ma)
Mauna Loa
Kilauea
Lō'ihi
Lithosphere
PACIFIC PLATE
Asthenosphere
The hot spot remains in one location, but the Pacific plate continues to slowly move.
Motion of Pacific plate drags the plume head
THE HAWAIIAN HOT SPOT
Rising magma melts through the crust and forms a volcano
Mantle plume

Extending the Connections

Investigate Types of Volcanoes

Volcanoes have different sizes and shapes. They can also contain different types of rocks. Learn how scientists have classified different types of volcanoes. What are the characteristics of a composite volcano? What are the similarities and differences between cinder cone volcanoes and shield volcanoes?

Before you leave this page . . .

1. What is a volcano?
2. According to the theory of plate tectonics, describe two ways that volcanoes can form at plate boundaries.
3. What is a hot spot?
4. How do hot spots support the theory of plate tectonics?

CONCEPT 4

Mountain ranges can also form when continental crust collides.

Activity

Investigating B.C.'s Mountain Ranges

Obtain a copy of a topographic map that shows the mountain ranges of B.C. Use your own knowledge as well as research sources to answer these questions.

- How many mountain ranges are there, and where are they located?
- Which ones include volcanoes?
- What are the names and elevations of the tallest peaks in each range?
- What patterns do you notice about the directions that mountain ranges run? Use your understanding of plate tectonics to account for this.

The Rocky Mountains, shown in **Figure 4.19**, are 4800 km long and run from British Columbia to New Mexico in the United States. Mountain ranges contain many peaks grouped together in a continuous line that can be hundreds or even thousands of kilometres long. Also, their locations on Earth are not random. Scientists have carefully studied Earth's mountain ranges to learn how they might have formed millions of years ago. These spectacular structures hold detailed information about Earth's history and the role that plate tectonics may have played in their formation.

You have learned about how tectonic plate movements involving oceanic crust collisions can result in formation of volcanic mountains. There are also plate movements that produce mountains that are not volcanoes. Some of these collisions have produced the highest mountain peaks on Earth.

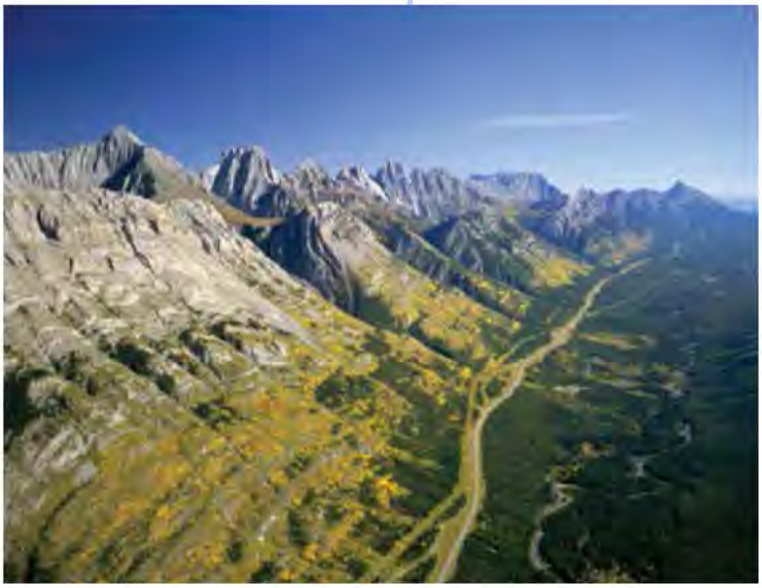


Figure 4.19 Mountain-building processes involving tectonic plate collisions resulted in the Rocky Mountains.

Continental Crust Collisions

Earth's tallest mountain ranges have been formed by collisions between plates of continental crust. Unlike when oceanic crust collides, continental crust is not easily subducted beneath the other plate. Instead, one plate is shoved beneath the edge of the other plate. This impact causes a large area to be pushed up, forming mountains, as shown in Figure 4.20. The collision also places large pressures on the plates. This produces features in the surrounding rock, such as faults, and causes the crust to become deformed.

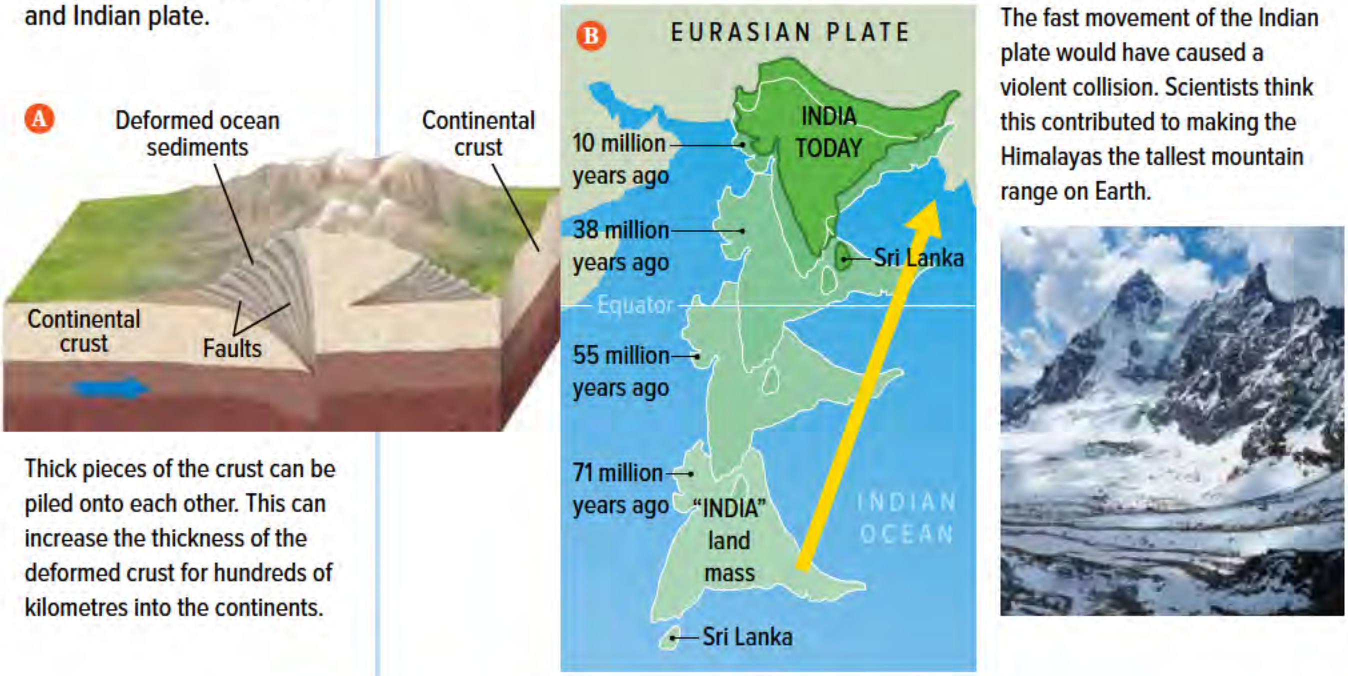

A
Deformed ocean sediments
Continental crust
Continental crust
Faults
B
EURASIAN PLATE
INDIA TODAY
10 million years ago
38 million years ago
Sri Lanka
Equator
55 million years ago
71 million years ago
"INDIA" land mass
INDIAN OCEAN
Sri Lanka

Figure 4.20 Ⓐ When two plates of continental crust collide, massive mountain ranges are formed. Ⓑ The Himalayan Mountain Range in southern Asia is thought to have formed from a collision between the Eurasian plate and Indian plate.

Thick pieces of the crust can be piled onto each other. This can increase the thickness of the deformed crust for hundreds of kilometres into the continents.

The fast movement of the Indian plate would have caused a violent collision. Scientists think this contributed to making the Himalayas the tallest mountain range on Earth.

Extending the Connections

How the Rocky Mountains Formed

The way that the Rocky Mountains are thought to have formed is complex and happened over many millions of years in certain phases. Find out how scientists think plate tectonics resulted in formation of the Rocky Mountains. How is the angle of the subducting plate related to the formation of this mountain range?

Before you leave this page . . .

1. Draw and label a sketch of a convergent plate boundary involving two plates of continental crust.
2. Why does the collision between plates of continental crust differ from what happens when oceanic crust collides with continental crust?

SCIENCE AT WORK

Focus on Earth Science

What kinds of jobs are there for people who study geological processes?

Communications Officer

Ethnographer

Volcanologist

Oceanographer

Pilot

Geological Technician

If you enjoy engaging with people as much as with machines and are as at home outdoors as indoors, then a geological technician might interest you. (Oh, and flying in helicopters!)

Seismologist

Can't decide between your passions for physics and geology? Have an interest in exploring fossil fuels or civil engineering? Seismology may be the right fit for you.

Surveyor

A knack for making exacting measurements, a keen eye, and a desire to determine precise boundaries may help to set surveyors apart.

Questions

1. What other jobs and careers do you know or can you think of that involve the study of Earth's plates and how they move?
2. Research a job or career related to Unit 4 that interests you. What attracts you to it? What kinds of things do you have to know, do, and understand for this job or career?

AT ISSUE

What's in a Name?

What's the Issue?

Within the Columbia Mountains of southeastern British Columbia lie the Selkirk Mountains, within which is the Valhalla range of mountains. And nestled amongst the Valhallas is a small yet distinctive peak whose official name is Mount Wilton. But ask the people of Winlaw, Vallican, Slocan Park, and others who can see this mountain from their homes in the Slocan Valley, and you are more likely to hear it called by another name—Frog Peak, in honour of the spirit animal sacred to the Sinixt Nation.

During the 19th and 20th centuries, many First Peoples traditional place names in British Columbia were replaced with colonial European names. Recently, some places have been renamed or co-named using their traditional names.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. Choose a landform, body of water, settlement area, or other place near where you live that has more than one name by which it is known. Trace the history of these names and why one may be used in preference to others.
2. How do the names of places become "official" to begin with? What is the process of changing an official place name, and under what circumstances can this process occur?

Check Your Understanding of **Topic 4.3**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Describe the relationship between tectonic plate boundaries and each of the following:
   - a) earthquake activity
   - b) volcanic activity
   - c) mountain formation PA

2. According to the theory of plate tectonics, describe what happens when two plates of oceanic crust collide. Use diagrams to support your answer. PA C

3. In a format of your choice, describe the relationship between the terms "fault," "epicentre," and "focus." C

4. Using a table, summarize three types of convergent boundaries and the geologic features that are formed at each.
   In your answer, include diagrams that represent each process. C

5. The San Andreas Fault in California is where the Pacific plate slides past the North American plate. What type of plate boundary exists there? What do you know about the geologic activity in this area? PA AI

Connecting Ideas

6. Millions of people all over the world live near volcanoes. Why do you think so many people would live in these regions? PA

7. In the early 1960s, the Canadian geologist John Tuzo Wilson developed a concept that is now considered a crucial milestone to the plate tectonics theory. It was important because it provided an explanation for a geologic feature that was not near any plate boundaries.
   - a) Describe what this contribution was and an example that supports it.
   - b) At the time, his idea was considered very radical. He could only get his paper published in a little-known journal at the time called the *Canadian Journal of Physics*. Why do you think he had such a difficult time getting his work published? PA

Making New Connections

8. Mountains have been the inspiration for many writers. Often their works include extensive knowledge of the mountain, with very descriptive passages about the mountain and its special features. The mountain can also be an important part of the plot, outcome, or character development.
   - a) Write a short fictional story or poem that includes a mountain in B.C. Identify the mountain and have it be a central part of your story or poem. Be sure to include important features of the mountain.
   - b) Explain why you chose that mountain to be part of your story. AI C

INVESTIGATION

4-E

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing Data
- Evaluating
- Applying and Innovating

What You Need

- access to online, print, and living sources of information

British Columbia's Earthquakes: Past and Present

Today, state-of-the-art technologies help scientists monitor and record earthquake activity as it happens. However, long before this technology was invented, First Peoples recorded major events through the use of oral histories and narratives. One example in shown in the box on the next page.

In this investigation, you will reflect on how the ways of knowing of First Peoples and the ways of knowing of western science and technology can help us understand earthquake activity in British Columbia.

Question

How do different ways of knowing complement our understanding of earthquake activity?

Procedure

1. Read through the entire procedure to determine the information you need to research. Then do the following.
   - Decide what resources you will use. Have your teacher approve the resources.
   - Decide how your group will work together to find, combine, and present the information.
2. Research technologies used to monitor earthquake activity. Make a list of questions that you want to find answers to. As part of your research, include:
   - a description of a technology and how it works
   - how data are collected and analyzed
   - how often earthquakes happen in B.C. and what the magnitudes typically are.
3. News reports about earthquake activity in B.C. often refer to "The Big One", which is predicted to happen. Find out what this is and the evidence for it.

Earthquake Foot

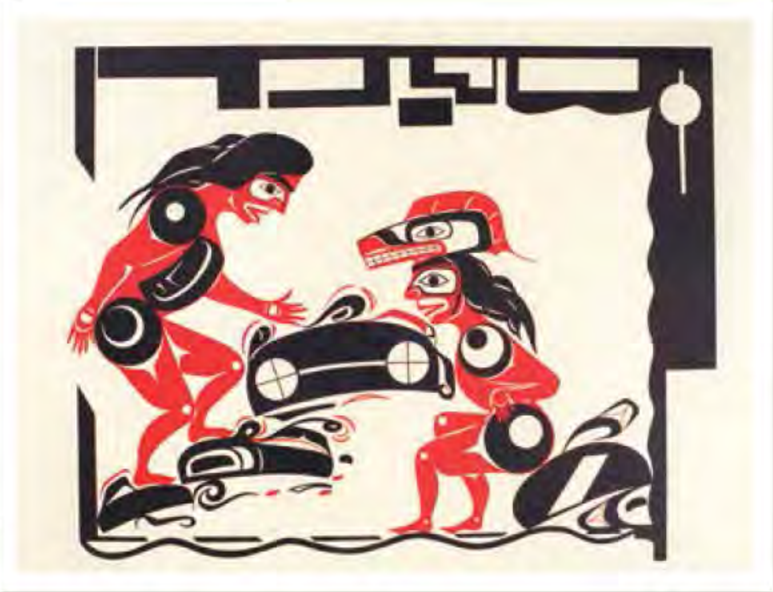
by Tim Paul, Nuu-chah-nulth

In speaking about this work, Tim Paul relates:

The Earthquake is our eleventh relative. We as a people must prepare ourselves each day and give thanks for all good things. We converse with the Maker when the moon is growing at the time of the new moon. Sometimes we take more than we need and do not put enough back. Our earthquake relative quickly reminds us of who we are and what we are entitled to. He will get angry and step out of his home in the mountain.

The earthquake is four dwarf-like people figures who live inside the mountain. When they see a passer-by they begin to sing and dance and try to entice the visitor into joining them in the celebration. If lured into the dance, the visitor will be forced to dance until tired and eventually to stumble into the large central drum. When the foot makes contact with the drum, it becomes infected with what is called Earthquake Foot and with each step the earth begins to tremble until it causes an earthquake.

Tim Paul



Source: Spirit Wrestler Gallery

4. Research the 1700 Cascadia earthquake and the role of First Peoples oral histories in reconstructing this event. (This earthquake is the one that created the Ghost Forest featured in the opening to this unit.)

Process and Analyze

1. Describe how important First Nations' history has been in providing knowledge of the 1700 Cascadia Earthquake.

Evaluate, Apply, and Communicate

2. Reflect on and respond to the Question posed to start this Investigation. Support your opinions with evidence.

INVESTIGATION

4-F

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

What You Need

Possible materials:

- small pieces of wood
- box
- string
- roll of paper
- pen
- soup can

Make Your Own Seismograph

A seismograph is an instrument used by scientists to measure the strength of the seismic waves produced from an earthquake. In this investigation, you will design and build your own seismograph.

Question

How can a seismograph be made using simple materials?

Procedure

1. Work with your group to decide how you will design, build, and operate your seismograph. A good design should
    - require inexpensive materials that can be easily found,
    - be able to show the strength of each vibration it measures, and
    - be able to measure continuously for at least a minute and be sensitive enough to detect small vibrations.
2. Draw and label your design.
3. Make a list of materials you will need and develop a plan for how to build your model. Make sure your teacher approves your plan and materials.
4. Build your model.
5. Demonstrate your seismograph for other students.

Analyze and Interpret

1. How sensitive was your seismograph? Overall, how well did it work?
2. Describe any challenges you had building your model or demonstrating how it works.

Conclude and Communicate

3. Compare your model with those of your classmates. How are they the same? How are they different? Did one model work better than others? If so, in what way was it better?
4. What improvements could you make to your seismograph based on other groups' designs?

INVESTIGATION
4-G

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

British Columbia's Volcanoes and Their Oral Histories

The Nass Valley in northwestern B.C. is the last place where a volcano erupted here. It happened more than 250 years ago, killing more than 2000 people. Two of the four villages of the Nisga'a First Nation were buried. There is a traditional Nisga'a oral history to explain the eruption, and it provides lessons from the Elders.

Procedure

1. Find an example of a volcanic eruption that has occurred in or near your region. If there isn't one, use the Nass Valley or another example from B.C.
2. Write out any questions you have about the eruption.
3. Decide which questions you will investigate, and plan how you will answer them. As part of your plan, find traditional oral histories associated with the eruption. How do or can they contribute to the process of scientific inquiry undertaken by geologists and other scientists?
4. Carry out your plan.

Analyze and Interpret

1. What effect did the eruption have on the people in the area? What lasting effect, on the landscape or people, has the eruption had?

Conclude and Communicate

2. How does considering different ways of knowing, including First Peoples and Western scientific ways of knowing, benefit the study of geological processes such as volcanoes?
3. Develop a creative way of sharing what you learned about the volcanic eruption you researched. This can include a recording, a dramatization, or a song.

TOPIC

4.4

How do geological features and processes affect where and how we live?

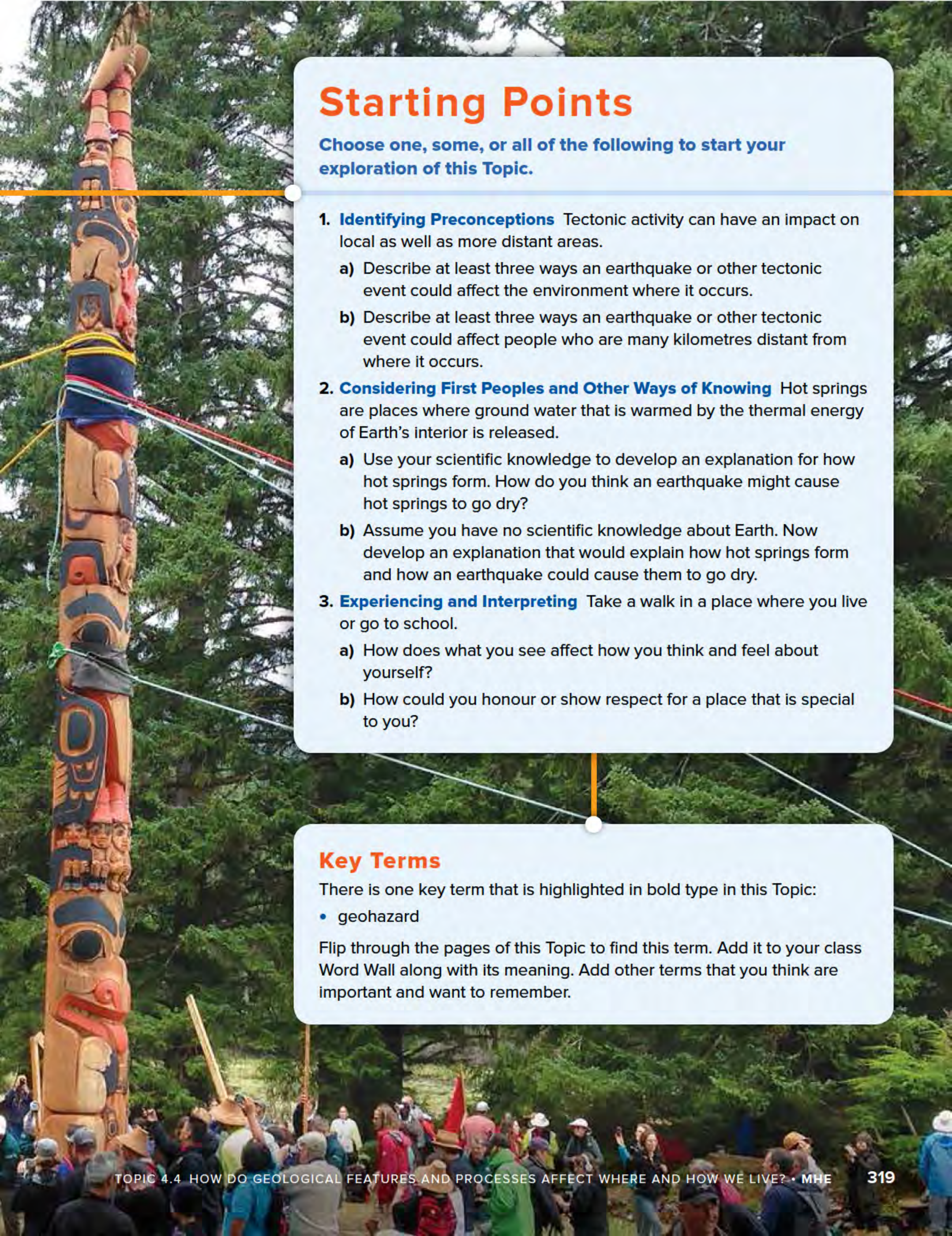
Key Concepts

- The geological history of British Columbia helps shape our lives.
- We use our knowledge of geological processes to help keep us safe.

Curricular Competencies

- Demonstrate a sustained intellectual curiosity.
- Make observations about the natural world.
- Transfer and apply learning to new environments.
- Communicate ideas and findings using scientific language.
- Express and reflect on a variety of experiences and perspectives of place.

The Gwaii Haanas Legacy Pole commemorates the 20th anniversary of an agreement between the Haida Nation and the Government of Canada that created the Gwaii Haanas National Park Reserve and the Haida Heritage Site. Shortly before completing it, carver Jaalen Edenshaw decided to add the figure of Sacred-One-Standing-and-Moving near the top of the pole. A story tells of this being holding Haida Gwaii steady with a tall pole on his chest, but now and then a pine marten races along the pole, creating vibrations that cause earthquakes. After the legacy pole was finished, a reminder of this story occurred. In 2012, a 7.7 magnitude earthquake stopped the flow of hot water to the hot springs of Hotspring Island on Haida Gwaii. Some promising signs of return were observed three years later. But it is not known how tectonic activity "shut off" the flow in the first place or whether the springs will ever recover fully.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Tectonic activity can have an impact on local as well as more distant areas.
   - **a)** Describe at least three ways an earthquake or other tectonic event could affect the environment where it occurs.
   - **b)** Describe at least three ways an earthquake or other tectonic event could affect people who are many kilometres distant from where it occurs.
2. **Considering First Peoples and Other Ways of Knowing** Hot springs are places where ground water that is warmed by the thermal energy of Earth's interior is released.
   - **a)** Use your scientific knowledge to develop an explanation for how hot springs form. How do you think an earthquake might cause hot springs to go dry?
   - **b)** Assume you have no scientific knowledge about Earth. Now develop an explanation that would explain how hot springs form and how an earthquake could cause them to go dry.
3. **Experiencing and Interpreting** Take a walk in a place where you live or go to school.
   - **a)** How does what you see affect how you think and feel about yourself?
   - **b)** How could you honour or show respect for a place that is special to you?

Key Terms

There is one key term that is highlighted in bold type in this Topic:

- geohazard

Flip through the pages of this Topic to find this term. Add it to your class Word Wall along with its meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

The geological history of British Columbia helps shape our lives.

Activity

Reflecting on Connections

How are you connected to where you live? How would you feel if you had to move? What places would you miss? Why would you miss them?

Plate tectonics explains British Columbia's geological processes. And those processes have quite literally shaped the landscapes—the places—that each of you knows, walks, and visits. Specific features of the landscape such as soil quality, salmon spawning areas, river deltas, mineral deposits, and hot springs have influenced the patterns of settlement that have taken place over the history of British Columbia, and long before it was given that name. Figure 4.21 shows a small sample of the present-day effects of the province's geological history.

Connect to Investigation 4-H on page 326

Activity

Your Place, Your Province

Pick one of the regions outlined in Figure 4.21. Learn about its population, the geological and other features that have brought people to it, and distinctive expressions of the peoples and cultures that call the region home. How can you connect with other classes in the province to create your own unique version and vision of the peoples and places of British Columbia?

Before you leave this page . . .

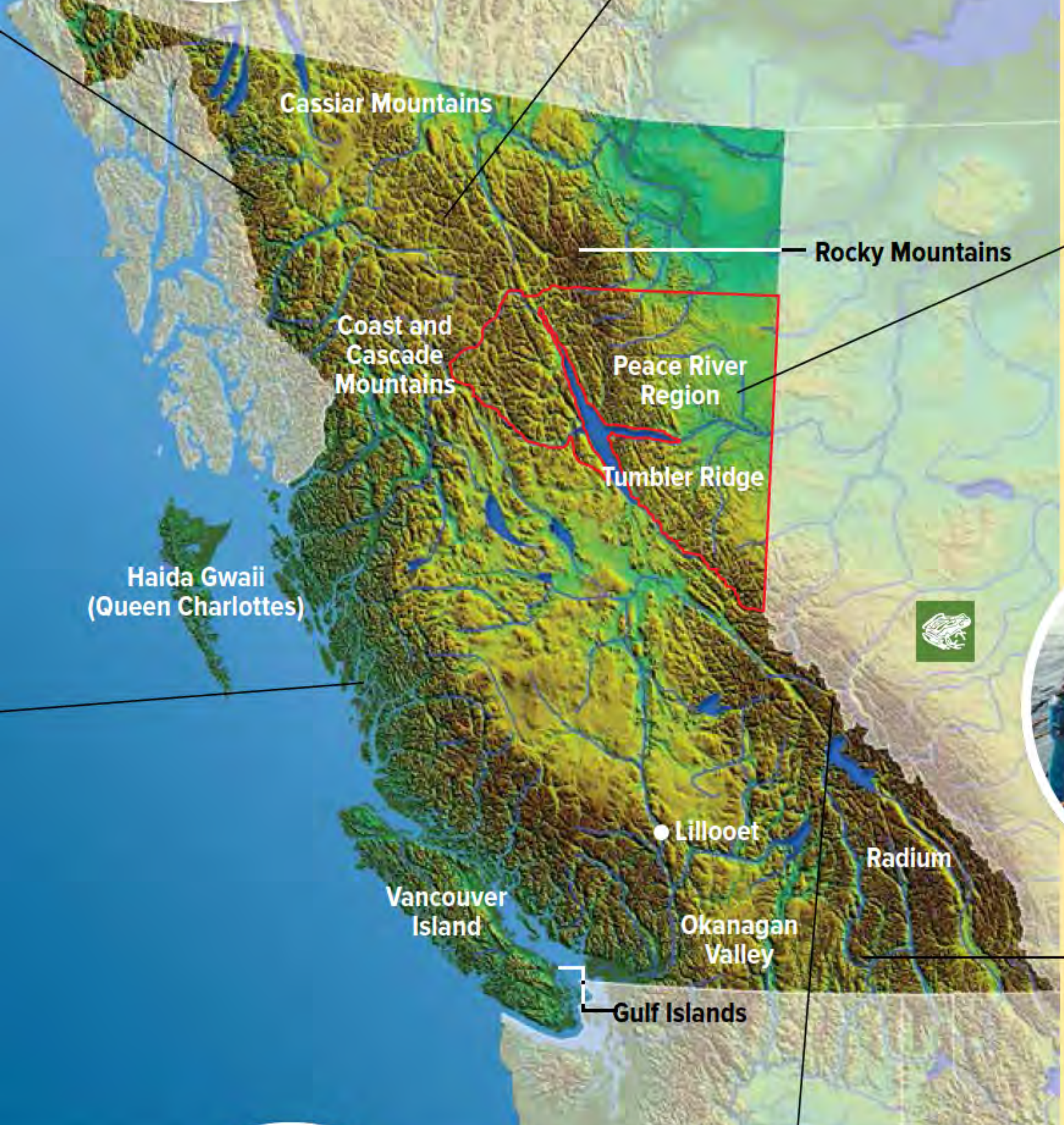
1. You have been asked to write a 30 second Internet ad that describes your part of B.C. What features would you focus on? Explain why you chose them.

Figure 4.21 The geology of different parts of the province has a powerful impact on the economic, social, and cultural characteristics of a region.

The coast includes the Coast and Cascade Mountains, as well as Haida Gwaii, Vancouver Island, and the Gulf Islands. Much of this region experiences earthquake activity, and there are mountains of dormant volcanoes. Great numbers of tourists are drawn here each year to discover and/or re-experience what the millions who inhabit the region have known for thousands of years.

In the northern interior, glaciers from the last Ice Age have carved out the many lakes that dot the landscape and have left behind nutrient-rich soils for farming. The Cassiar Mountains have rock from ancient ocean crust that collided with the North American plate more than 200 million years ago. The oceanic rock contains deposits of valuable jade.

The northeast includes the Peace River Region. Its soils, so rich for farming, were once the bottom of an ancient glacial lake. The area also has deposits of natural gas, oil, and coal. In addition to waterfalls, caves, and other scenic splendours, Tumbler Ridge also boasts fossils of marine fish and reptiles that date back over 200 million years ago. And nine of the fourteen known tyrannosaur tracks in the world are found here.


Cassiar Mountains
Rocky Mountains
Coast and Cascade Mountains
Peace River Region
Tumbler Ridge
Haida Gwaii (Queen Charlottes)
Lillooet
Radium
Vancouver Island
Okanagan Valley
Gulf Islands

The southern interior includes steep-walled canyons with flowing rivers. Near Lillooet, the Bridge River and Fraser River meet to create an important fishing site for the St'át'imc First Nations. The Okanagan Valley is most known for its lakes and agriculture. The architecture of many towns reflects the wealth that came from silver, gold, and copper mines.

The Rocky Mountains run through the southeast and extend toward the north end of the province. Mount Robson, found here, is Canada's highest peak. And North America's longest mountain valley, The Rocky Mountain Trench, runs along the west side of the Rockies. Water rises at faults in Earth's crust in this valley, producing world-famous hot springs such as those at Radium.

CONCEPT 2

We use our knowledge of geological processes to help keep us safe.

Activity

Do you think...

- you could outrun a landslide or an avalanche?
- you could keep your balance if you were caught in a flash flood?

Do you know...

- what kinds of events can trigger a slide of land, mud, or snow?
- what to do in the event of a natural hazard such as an earthquake or landslide?

Millions of people all over the world live in places that can experience natural hazards such as earthquakes and landslides. These are examples of **geohazards**, which are destructive events that result from geological processes. Such events pose threats—short term, long term, or both—to people, property, and the environment. Figure 4.22 shows an example.

geohazard a destructive event that results from geological processes

Many factors combine to make British Columbia vulnerable to geohazards. These factors include the substantial amounts of rain and snow that fall each year, its geological makeup, and large amounts of sediments laid down by glaciers. And, of course, the province is located in an active tectonic region.

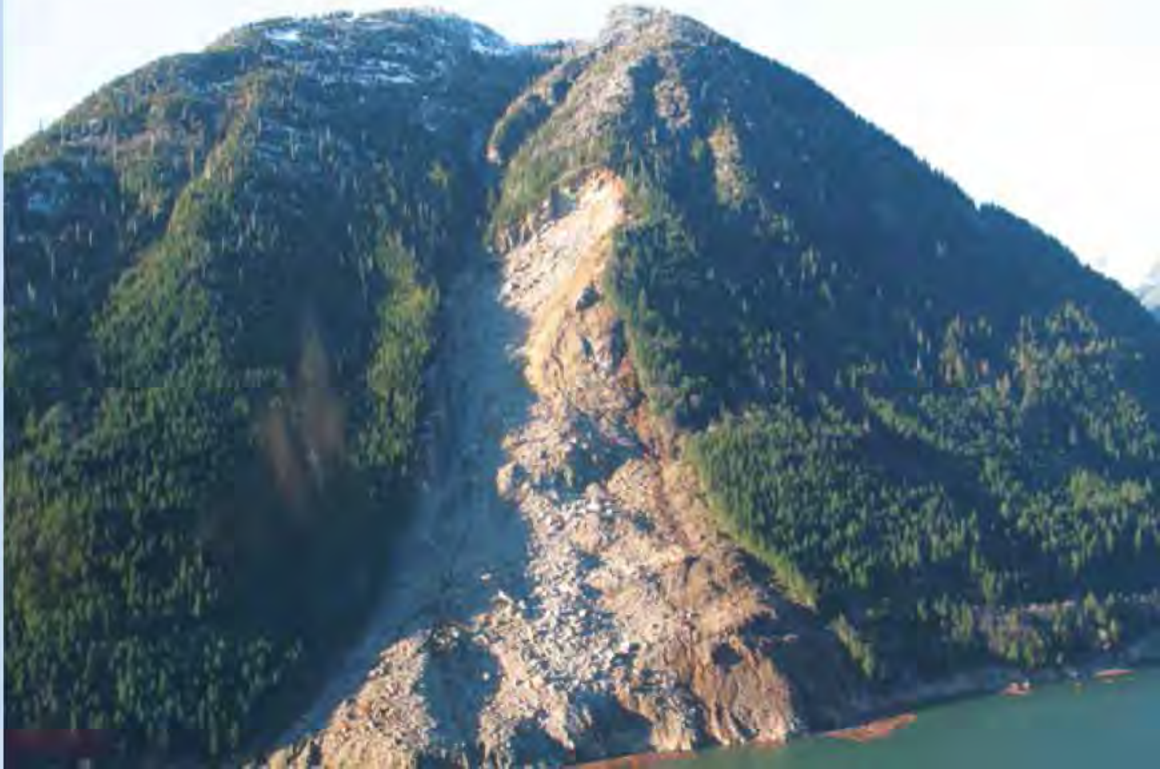


Figure 4.22 In 2007, about 500 000 cubic metres of rock, sediment, and vegetation poured down a mountain slope into Chehalis Lake, near Chilliwack. The resulting waves pounded the shoreline with scouring force and threatened nearby areas with flooding.

Being Aware, Being Prepared

At the start of this unit, you saw a photo of the Neskowin Ghost Forest, which showed the aftermath of the last time that two plates of the Cascadia subduction zone suddenly slipped. The resulting powerful megathrust earthquake not only wiped out villages along the Pacific Northwest coast, but also sent 3-storey waves on a 10-hour journey across the ocean to Japan, where they damaged homes on Honshu Island.

Connect to Investigation 4-I on page 327

The map in **Figure 4.23** marks earthquake activity in Canada in recent history. You can see that the most active region is in southwestern B.C. and off the coast. At this time, there is no reliable way to accurately predict when and where the next earthquake or other geohazard will happen—in B.C. or anywhere else in Canada or the rest of the world. But awareness leads to preparedness.

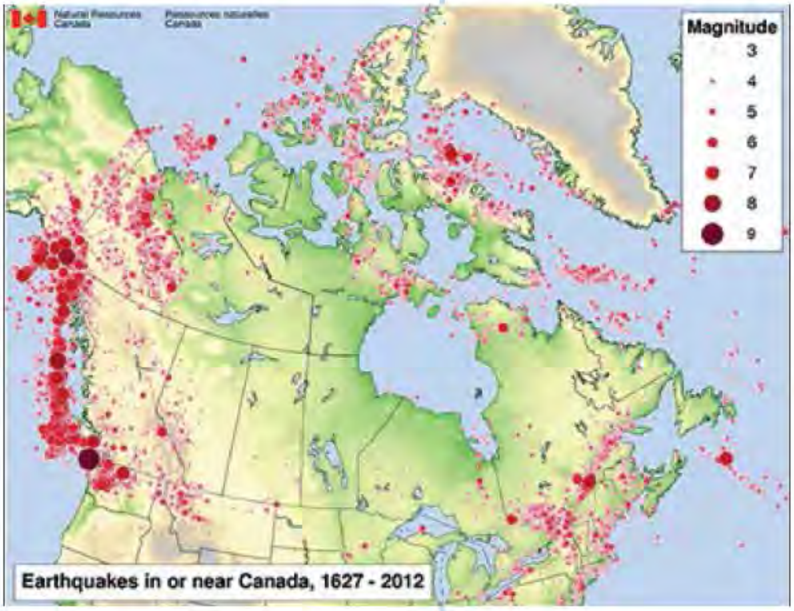

Natural Resources Canada
Ressources naturelles Canada
Magnitude
3
4
5
6
7
8
9
Earthquakes in or near Canada, 1627 - 2012

Figure 4.23 Western and southwestern British Columbia experiences more than 300 earthquakes each year. Most are so small that they only register on sensing equipment. But devastating, large magnitude earthquakes have happened before, and they will happen again.

Activity

How Can You Stay Safe in the Places You Live?

Describe a geohazard that has affected where you live and/or could affect your region in the future. Consider how the presence of human communities can affect the impact of a hazard. What is your responsibility, and that of other community members, during such an event? Develop a safety plan for your family to follow if the hazard happens. Assign specific tasks to each member of your family.

Before you leave this page . . .

1. What is a geohazard? Give an example of a geohazard in your area.

TAKE Action

Make a Difference

How can we make the places we live safer?

Most of the damage that results from earthquakes is caused by the collapse of buildings, bridges, and other structures. The damage may happen as a direct result from the ground shaking, or it may occur later due to tsunamis, flooding, or fires caused by the event.

The provincial and federal governments have apps, websites, and publications aimed at helping people stay safe in the event of a geohazard. Depending on where you live in B.C., you may have special drills that you practise each year. Still, many people remain unprepared for an emergency.

Question and Plan

1. Think about how you might prepare for an earthquake or other geohazard in your own home. What questions do you need to consider?
2. Develop an emergency plan for your home and family.

Communicate

3. How can you make sure that everyone at home understands and will follow your emergency plan?

Apply and Innovate

4. Think beyond your home. How can you modify your plan so that it is suitable in your community? How will questions change? What can you do to get the message out to a larger number of people spread out over a larger area?

← Tofino
H
17 km
→ Ucluelet
24 km
TSUNAMI
EVACUATION ROUTE
CHEMIN D'ÉVACUATION
→

Check Your Understanding of **Topic 4.4**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Why do people who live in British Columbia need to be especially aware of geohazards? Provide two reasons to support your answer. PA E

2. Describe a geohazard that has happened or may happen in the area you live. How prepared are you to deal with its effects? What can you do to increase your level of preparedness? AI C

3. Give two examples of how geological processes have influenced the region where you live. PA E C

Connecting Ideas

4. In planning to be prepared for a geohazard, describe what you think the responsibilities are for the following people.
   - **a)** individuals and their families
   - **b)** local city or town government officials
   - **c)** emergency response personnel
   - **d)** provincial and national assistance agencies E AI C

5. In 2016, the provincial government spent or committed about $2 billion to upgrade or replace 214 out of 342 schools that had been identified as being at risk in the event of an earthquake.
   - **a)** What factors do you think governments should consider when deciding how to fund projects like these, which are informed by reliable scientific information?
   - **b)** What ideas do you have that could provide funding for all schools that are at risk? QP E AI

6. Use a table like the one below to describe the different impacts geohazards can have. Include at least two geohazards. PA E AI C

Economic Impact	Social and Cultural Impact	Environmental Impact	Political Impact

Making New Connections

7. The Celtic poet and philosopher, John O'Donohue, reflecting on the connections between people and places, once wrote: "Is it not possible that a place could have huge affection for those who dwell there? Perhaps your place loves having you there. It misses you when you are away and in its secret way rejoices when you return. Could it be possible that a landscape might have a deep friendship with you? That it could sense your presence and feel the care you extend towards it?"
   - **a)** Express your views on this passage.
   - **b)** In what ways does this passage express ideas that are similar to First Peoples ways of thinking about place and identity? E AI C

8. Re-read the first sentence of Concept 2. Why might people choose to live in places where there is a demonstrated history of geohazards? What features of land, culture, and/or economy could override the potential risks? PA AI

INVESTIGATION

4-H

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

A Sense of Place

In this investigation, you will consider the place in which you live and the features that make it special or unique to you.

Procedure

1. Think about the area that you live in and why it feels special to you.
2. Make a list of geologically related features of the area that you feel a connection with or that make the place unique. Also list other features about where you live that you feel make it special. This could be the history, culture, family members, plants, or animals of the area.
3. Plan how you want to represent these features. For example, you can collect items, take photographs, and draw maps.
4. Think of how you want to communicate your sense of place. For example, you could develop a display of these features in a display case that you make.
5. Have your teacher approve your plan before you start collecting the materials.
6. Carry out your plan.

Analyze and Interpret

1. Present your display to other classmates. Write down the different ways that your classmates represented their sense of place. How did it compare with yours? How different or similar are they? Why do you think there are differences, even though you live in the same area?

Conclude and Communicate

2. A person's sense of place develops from identifying himself or herself in relation to a landscape or area. How does the place you live influence how you think about yourself?

INVESTIGATION

4-1

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

What You Need

Possible materials:

- toothpicks
- straws
- pieces of foam
- stir sticks
- pieces of polystyrene
- cardboard
- scissors
- tape
- glue
- metric ruler

How Earthquake-Proof Is Your Structure?

Engineers spend a great deal of time designing buildings, bridges, roads, and other structures that can withstand seismic waves from earthquakes. The model structures are tested using shake tables. Shake tables model seismic waves under controlled conditions. In this investigation, you will design and build a structure, then test the structure's stability using a shake table.

Question

How earthquake-proof is a model structure?

Procedure

1. In a group, design a model building or other structure that is at least 0.3 m high. Your goal is to design a structure that can withstand a 1-minute imitation earthquake on a shake table.
2. Decide how you will rate the level of stability of your structure.
3. Draw and label your design.
4. Make a list of materials you will need and have your teacher approve them.
5. Build your model.
6. Test your model using a shake table. Make any improvements to your structure before testing it for 1 continuous minute on the shake table.

Analyze and Interpret

1. Describe what happened to your building when you tested it. Why do you think this happened?

Conclude and Communicate

2. Compare your structures and results to those of your classmates. Which structures tested the best? Which structures were the least stable? Why do you think some structures were more stable than others?

TAKE a Stand

Make a Difference

Who Should Bear the Responsibility?

There are many ways that people can find themselves in danger. Perhaps they have gone hiking, skiing, or sledding out of bounds. Maybe a geohazard or other natural disaster is occurring, and people are told to leave or to be prepared to leave on short notice.

Who Should Pay the Cost of Being Rescued?

The ropes barring access to the ski hill sent a clear message: stay out. But a family of six, enjoying a day of skiing at Sun Peaks Resort in 2016, ignored the warning, and soon found themselves in need of help from Kamloops Search and Rescue. The family later made a donation to the search and rescue operation to express gratitude and to acknowledge that heading out of bounds in the first place was a mistake.

The official position of the B.C. Search and Rescue Association is that it will not charge for people who need the services of its nearly 2500 volunteers.

> The British Columbia Search and Rescue Association (BCSARA) believes that the perceived or actual belief that a lost or injured person or their loved ones will be charged for a search and rescue response could directly affect the decision as to if or when a call for professional help will be made.…The BCSARA will conduct search and rescue missions when requested to do so by the authorized tasking agencies for persons in danger or distress in the province of BC without charge. We will do so regardless of the reason they have found themselves requiring our assistance.

Who Should Be Responsible for Personal and Community Safety?

A disaster is occurring or looming. Earthquake, tsunami, fire, flood, mudslide—whatever the cause, you have been given an evacuation order. This means you have been told that you are at risk and must leave the area immediately. What if you choose to stay? *Can* you choose to stay—to ignore the order? The B.C. government began to consider changes to the current Emergency Program Act in January of 2016.

While the Act provides authority for local governments or the Ministry to make an evacuation order and "cause the evacuation" of people from an affected area, it says little of anything about how such an order is to be understood and carried out to ensure people are out of harm's way. There is currently no authority under the Act or in other legislation to compel competent adults to leave their private property after an evacuation order is made—emergency responders warn people of the imminent risks of remaining in an area subject to evacuation, but ultimately rely on people to [voluntarily] evacuate.

Question and Analyze

1. Two types of situations are presented here. What do they have in common? In what ways are they different?

Evaluate and Communicate

2. Reflect on the questions used as titles for this feature. What are your views? Why do you hold them? What additional questions and/or information would either help you be more certain of your views or make you consider changing them?
3. Hold a class debate about a question or issue related to the matter of personal and/or collective responsibility in dangerous situations.